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ABSTRACT

This manual was developed for use at workshops designed to upgrade the knowledge of experienced water and wastewater treatment plant operators. The course consists of lecture-discussions and hands-on activities. Each of the lessons has clearly stated behavioral objectives to tell the trainee what he should know or do after completing a topic. Areas covered in this manual include: hand tools and their uses, drawings and equipment manuals, maintenance of piping and valves, lubrication, bearings, alignment, pump maintenance, packing and seals. (CS)

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PREVENTIVE MAINTENANCE WORKSHOP

January, 1977

Training and Certification Section
Personnel Services Branch
Ministry of the Environment
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INTRODUCTION

The *Preventive Maintenance Workshop* manual has been prepared as a home study and reference manual for plant operators and as the text for the related workshop.

The principal objective of the Workshop is to upgrade the knowledge of experienced water and wastewater treatment plant operators. The lesson objectives are clearly indicated at the beginning of each topic and tell the operator what he must know or do after having covered the topic. Upon completion of the Workshop, the trainee is expected to attain a minimum level of competence of 70% for the course.

This is a working course in which each person is expected to take an active part in subject discussions. It includes hands-on participation, in order to provide as much practical knowledge as possible of good maintenance procedures.

The Training and Certification Section wishes to acknowledge the assistance and contributions of the following in the preparation of the manual:

Ministry of the Environment:
Regional Operations
Municipal Engineers Association
Various Manufacturers and Suppliers

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SUBJECT:

PREVENTIVE MAINTENANCE

TOPIC: 1

TOOLS AND WORKSHOP

OBJECTIVES:

The trainee will be able to:

1. Recall the basic tools required for normal maintenance.
2. Recall the use and care of the basic hand tools.
3. Recall the types of measuring devices used in maintenance and demonstrate their use.

HAND TOOLS AND THEIR USES

GENERAL

Hand tools and measuring devices are essential elements of any maintenance tool kit, being required for any repair job. Hand tools are used to remove, disassemble or adjust parts and units. Measuring devices are used for checking sizes and clearances.

All plant personnel must be thoroughly familiar with tools and measuring devices. It is also important to know how to use them correctly, so as to complete the work as quickly as possible, with maximum accuracy and safety. See Appendix A for suggested list of tools required at a treatment plant.

OPEN-END WRENCHES

Probably the most important tool is the open-end wrench, used for loosening or tightening bolts and nuts. American wrench sizes are designated by the width of the opening. A set of standard open-end wrenches usually has the smallest opening of 3/8 in. and increases in graduated sizes, with the largest opening being 1 1/4 in. Larger openings are also available, but are not always included in a set. While the smallest opening of a standard wrench set is usually 3/8 in., smaller wrenches known as miniature, are also available. Such wrenches are needed for work on, for example, ignition systems. The openings range in size in 1/32 in. steps from 3/16 in. to 15/32 in.

In order to be able to turn a nut in a restricted space, the end of the wrench is placed at an angle to the handle. Usually this is 15 degrees. By having first one

side of the wrench up, and then the other, it is possible to turn nuts in very restricted spaces. Wrenches are also made with openings at 22 1/2 deg., 30 deg., 60 deg., and 90 deg. to the handle.

BOX WRENCHES

To reduce the possibility of a wrench slipping from the nut, the box-type wrench was designed. Usually the box is a double hexagon (12 grooves). These grooves engage the corners of the nut. This permits moving the handle of the wrench through an arc of as little as 30 deg. The wrench can then be repositioned on the nut, an extremely important advantage, as the movement of the wrench handle is often restricted because of space limitations. Furthermore, as the walls of the box are relatively thin, less space surrounding the nut is required than is the case with the conventional open-end wrench. The disadvantage to the box wrench is that it cannot be used on copper tubing fittings. However, a box-type wrench with a section of the box cut away, Figure 1-2, is available for such work.

In addition to the regular box wrenches with the straight handles, some have the heads set at an angle of 15 degrees to the handle. This tips the end of the wrench, which is not on the nut, upward, and provides clearance for the individual's knuckles.

SOCKET WRENCHES

Socket wrenches like the box wrench, completely surround the nut to be tightened or loosened, and there is little chance of the wrench slipping from the nut. Usually the socket wrench has 12 grooves to engage the corners of

the nut. They range in size from approximately 3/16 in. to 1/5 in. and they have detachable handles of various types. The opening in the socket in which the wrench handle is placed is 1/4 in., 3/8 in., 1/2 in., or 3/4 in., square. This is known as the "drive". In addition, one manufacturer has a socket wrench with 7/16 in. drive, which is designed to take the place of both the 3/8 in. and 1/2 in. drive socket sets.

Maintenance tool kits usually include a set of 1/2 in. drive socket wrenches, designed for use on nuts ranging in size from 3/8 in. to 1 5/16 in. The socket wrench set includes various types of handles, designed so that nuts in normally inaccessible positions can be reached. The time for their removal and replacement is greatly reduced. The following types are usually included: reversible ratchet handle, extensions of various lengths, speeder, cross handle, hinge or flex handle.

Inside the head of the ratchet handle is a pawl or dog which engages or fits into one or more of the ratchet teeth. On pulling the handle in one direction, the dog holds in the ratchet teeth and turns the socket. On moving the handle in the opposite direction, the dog ratchets over the teeth, permitting the handle to be backed up without moving the socket. As the teeth of the ratchet are relatively fine, the ratchet handle can be swung through a very small angle to get a new grip. By using a ratchet handle, it is not necessary to disengage the socket from the nut, and the nut can be quickly removed.

The speed handle, which is shaped like a carpenter's brace, is also designed for quick removal of the nut, and is used primarily after the nut has once been loosened by means

of another wrench providing greater leverage.

In many cases it is not possible to get a direct pull on a nut, and then a universal joint is used between the handle and socket. (Figure 1-1a).

TORQUE WRENCHES

In many cases it is essential that a nut be tightened a specified amount. If overtightened, the part on which the nut is mounted may be distorted and leakage of some sort may occur. This is particularly true in the case of cylinder head and bearing nuts and bolts. So that such nuts or bolts can be tightened the specified amount, a torque wrench is used. Torque wrenches are provided with an indicator which will show the amount of torque in either foot pounds or inch pounds. When using a torque wrench, it is imperative that the threads of the nut to be tightened are clean and oiled, so that no additional friction will be present. See Figure 1-1b for a typical torque wrench handle.

Torque wrenches are used with the socket of the size to fit the nut which is to be tightened.

ADJUSTABLE WRENCHES

There are two general types of adjustable wrenches. These include the adjustable-end wrench, and the pipe or Stillson wrench, Figure 1-1.

The adjustable-end wrench is convenient to have in a tool kit, as it will fit any nut which is within the range of its adjustment. It comes in various sizes, and is specified according to length. There are two disadvantages of an adjustable wrench. One is that they do not hold their

10" Adjustable

Pipe Wrench (Stillson)

Figure 1-1 Adjustable Wrenches

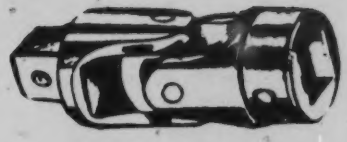


Figure 1-1a Universal Joint for Sockets

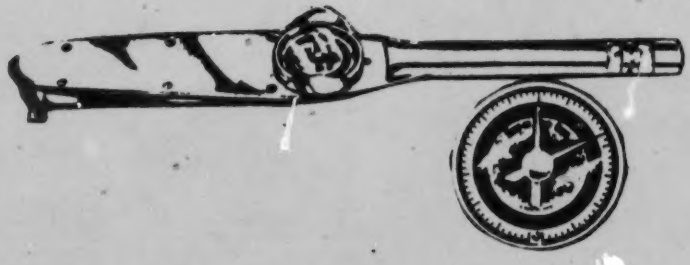
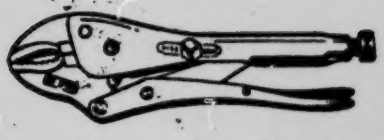


Figure 1-1b Torque Wrench

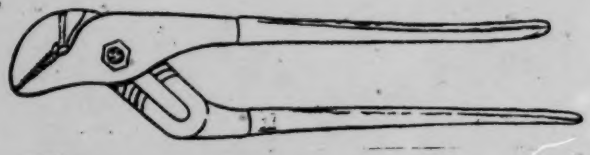
Slip Point

Needle Nose

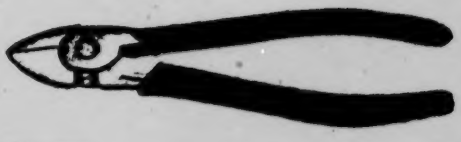
Duck Bill



Vise Grips



Channel-lock Pliers



Diagonal Cutters

Figure 1-2 Pliers

adjustment and consequently, they are apt to slip on the nut. Secondly, too much torque can be applied thereby doing damage to the nut or bolt.

The pipe wrench, as the name implies, is designed specifically for tightening and loosening pipes or other circular items.

Regardless of what type of wrench is being used, it must fit the nut or bolt head. If the wrench opening is too large for that particular nut it will slip and round off the corners of the nut. When the wrench slips, the operator may receive a skinned knuckle. It is always much safer to pull on a wrench than to push on it. Worn or damaged tools should be removed from service.

PLIERS

There are many different types of pliers, one of the most common being the 6 in. combination slip-joint plier, Figure 1-2. The slip-joint permits the jaws to be opened wider at the hinge for gripping larger diameters.

The diagonal cutting pliers, Figure 1-2, are needed not only for cutting wire but are also used extensively for removing cotter pins.

Long-nose pliers, Figure 1-2, either the flat nose or duck bill type, are needed frequently to aid in positioning small parts or in recovering a washer or a nut which has dropped into an inaccessible place.

The channel-lock plier, Figure 1-2, is a variation of the slip-joint plier in that it is adjustable. The opening of the plier can be adjusted to several different sizes, by means of a dog which engages any one of the circular channels. In that way the jaws of the plier remain approximately parallel regardless of the size of the opening.

One of the most versatile tools is the vise-grip or locking plier, Figure 1-2. When locked in position on a part, it will grip firmly even though the area contacted by the jaws of the pliers is extremely small. It has an infinite number of uses ranging from holding two parts together while they are being worked on, to gripping the end of a broken stud and turning it out of its threaded hole.

Pliers and pipe wrenches should never be used for loosening or tightening nuts.

SCREWDRIVERS

Many different types and sizes of screwdrivers are needed. The usual length of screwdrivers is 3, 4, 6, 8, 10, and 12 inches. A complete set is essential.

The conventional screwdriver, has a flat blade designed to engage a straight groove in the head of the screw. The Phillips-type screwdriver has a pointed end with four grooves which are designed to engage corresponding slots in the head of the Phillips-type screw. The Robertson screwdriver has a squared end and the most commonly used sizes are designated by colour - green, red and black. When the space over the head of a screw is limited, an offset screwdriver is needed to remove or tighten the screw. These are available in different sizes, and can also be obtained with ratchet heads.

Screwdrivers should only be used on screws. They should fit the screw slot snugly, as a loose fit will not only damage the screw head but also the screwdriver blade. They are not designed to be used as levers or pry bars.

SETSCREW WRENCHES ("ALLEN" KEYS)

Setscrew wrenches, or Allen wrenches are used on set screws with hexagonal recesses in the screw heads. These wrenches are L-shaped bars of steel. A typical set comprises eleven wrenches ranging in size from .050 to 3/8 in., and are designed to fit set screw sizes #4 to 3/4 in. Hook spanner or '6' wrenches are used to tighten and loosen round nuts which have a series of notches cut into the outer edge. For the most part, these are special wrenches furnished by the manufacturer to service special parts.

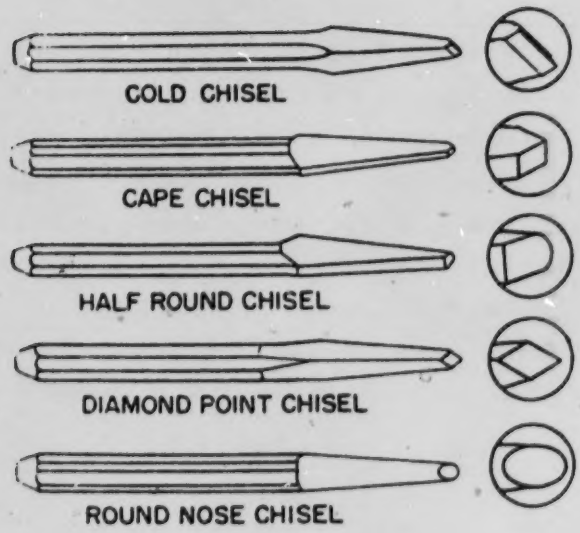
HAMMERS

Hammers of various types and sizes are required. The most important is the ball-peen hammer, Figure 1-3. The flat portion of the head used for most hammering is called the face, and the other end the peen. When the peen is ball shaped it is known as a ball peen, and is used primarily for riveting work.

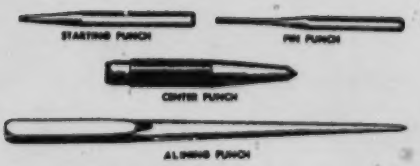
Ball-peen hammers are usually classed according to the weight of the head without the handle. A good combination hammer set would include 12 oz., 1/2 lb. and 4 oz. hammers. A smaller hammer is very handy for light work, especially when cutting gaskets out of sheet stock.

Simple as the hammer is, there are right and wrong ways to use it. The beginner usually has a tendency to

Ball Peen Hammer



Cold Chisels



Punches

Figure 1-3 Hammer, Chisels, Punches

grip the handle too close to the head. This is known as choking a hammer, and reduces the force of the blow. By gripping the hammer close to the end of the handle, a heavier blow can be struck with less effort. The full face of the hammer should contact the head of the chisel or other work.

Never work with a hammer having a loose or "mushroomed" head. This may cause injury because the head of the hammer or chips from the mushroomed head may fly off.

The end of the hammer handle should not be used for bumping purposes, as this will quickly split and ruin the handle. Neither should hammer handles be used as levers.

If there is any danger of damaging the surface or work, a "soft" hammer, should be used. Special hammers with faces of raw hide, plastic or lead are available.

CHISELS

Cold chisels, Figure 1-3, are used for cutting metal, to cut the heads from rivets, chip metal, and to split nuts which have become rusted and cannot be loosened by means of a wrench. The cape chisel has a narrow cutting edge and is used primarily for cutting keyways and narrow grooves. In general, most maintenance work will require the use of only the flat chisel, and the sizes most frequently used are 3/8 in., 1/2 in., and 3/4 in.

When using a chisel, a right handed person should hold the tool in his left hand, and wield the hammer with his right. The chisel should be held rather loosely with fingers curled around the chisel about one inch from the head of the chisel.

When chipping metal, the depth of the cut is controlled by the angle of the chisel. Deeper cuts are taken as the angle of the chisel approaches the vertical. *When chipping, the operator should keep his eye on the cutting edge, and not the head of the chisel.*

Goggles should be worn when chipping and grinding, and precautions should be taken so that chips will not strike anyone who is nearby. Never use a chisel on which the head has mushroomed, as portions of the "mushroom" will fly off when struck by a hammer. The battered end should be ground off on a grinding wheel.

PUNCHES

A variety of punches are required. The starting punch, or drift as it is sometimes known, is designed to punch out rivets after the heads have been cut off. These punches are also used to start driving out straight or tapered pins, Figure 1-3. After the pin has been driven partly from the hole, the starting punch can no longer be used because of its taper. A pin punch is then used to complete the job, but should not be used to start such work because a hard blow on the punch would bend the slender shank.

A lining-up punch has a long taper, and is used to shift parts to bring corresponding holes into alignment. The center punch is ground to a fine point, and is used to mark the location of a hole that is to be drilled. Without such a mark the drill will wander over the surface and the hole will be drilled at the wrong position.

METAL SHEARS

For cutting sheet metal and gasket material, heavy tin shears are needed. The straight-blade shear is the

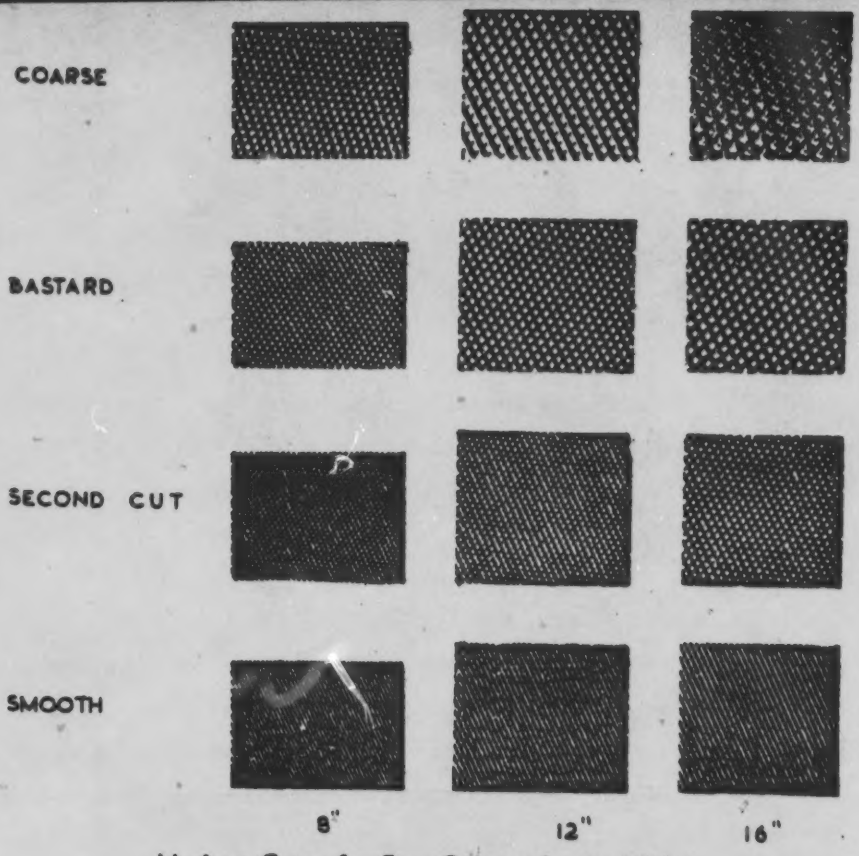
most commonly used type. The curved blade shears are also convenient to have available, for making curved cuts.

FILES

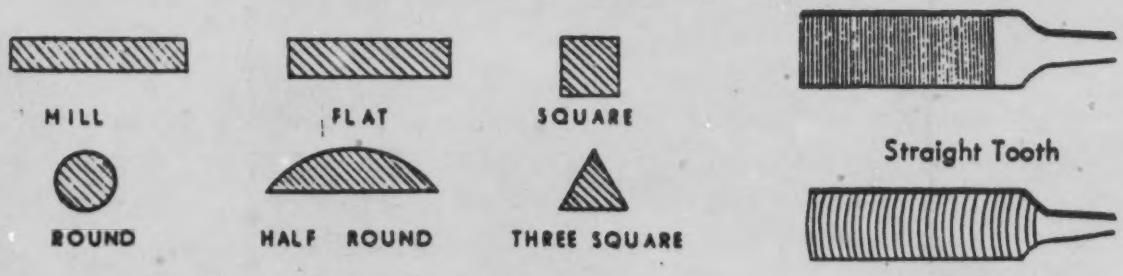
Files are hardened steel tools with diagonal rows of cutting edges or teeth which are used for smoothing, polishing and removing metal. There are more than 20 types of files, each type having a size range of 3 to 18 in.

Files are graded according to the tooth spacing. The terms used to indicate the coarseness or fineness of a file are: rough course, middle-cut, bastard, second-cut, smooth, and dead smooth. A file with a single row of parallel teeth is called a single-cut file. Files which have one row of teeth crossing another row in a criss-cross pattern are called double-cut files. A file may be either single cut or double cut.

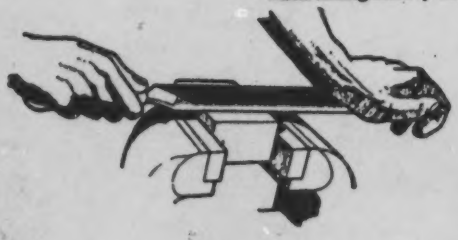
There are many different shapes in which files are available, Figure 1-4. The mill file is single-cut, tapering in thickness and width for one-third of its length. It is used primarily for fine work and is available with either square or round edges or with one safe edge, one without teeth. A double-cut file, tapering in thickness and width is known as a flat file. It is used when a faster cut is desired. The hand file is single cut and similar in shape to a flat file, with parallel sides and a slight taper thickness. It has square edges one of which is a safe edge. For rough filing, the bastard file is used.



Various Cuts of a Few Commonly used Files



Common Shapes of Files



The correct method of holding a file when taking a heavy cut on a flat surface.

Reducing the diameter of a bar by filing. The dotted circle represents a metal washer used to protect the vice jaws and to aid in forming a true shoulder on the work.

Figure 1-4 Files and their Correct Use

The round file is tapered and usually single cut. In larger sizes it is also available in double cut. For enlarging large holes, a round 12 in. bastard file is usually used. If the hole is of small diameter, a round 6 in. file, usually known as a rat-tail is used. In addition to the tapered round file, there are also untapered round files available. The principal use of round files is to enlarge circular openings and file concave surfaces.

The half-round file is a double-cut file tapering in thickness and width, and with one flat and one oval side. It is used mainly for rough filing on concave surfaces.

The triangular file is useful for filing small notches, square or cornered holes. In addition, it is frequently used for recutting mashed and damaged threads on bolts and other parts and sharpening wood saws.

The type of metal must be considered when selecting a file. As previously pointed out, files with course teeth are used when it is desired to remove a lot of metal as quickly as possible. Files with fine teeth remove less metal, but produce a smoother surface.

When filing cast iron, a bastard-cut file should first be used and a second-cut file for finishing. On soft steel, a second-cut file is used first, and a smooth-cut for finishing. On hard steel, filing is started with a smooth-cut and finished with a dead-smooth file.

On soft metals such as brass or bronze, a bastard-cut is used first and then a second-cut. On aluminum, babbitt or lead, a Vixen-cut file is preferred. If that type of file is not available, a bastard-cut file may be used.

Files should never be used without a handle. *The pointed tange may be driven into the palm of the mechanic's hand, inflicting a bad wound. Files should never be used as levers. Files are brittle and will quickly break, if hammered on or used as levers.*

The correct way to hold a file is shown in Figure 1-4. A right-handed mechanic will grasp the file handle in his right hand. The end of the file is held in the left hand with the fingers curled over the end. His feet should be spread apart and his body should lean slightly forward so that his left shoulder will tend to be over the work. In order that a flat surface is filed, the forward movement of the file must be perfectly horizontal. When filing a round surface, the file should be rocked.

Whenever possible, the work to be filed should be clamped in the jaws of a vise. If the work is of soft metal, the jaws of the vise should be covered with soft caps so that the work will not be marked or otherwise damaged.

File teeth are designed to cut only when the tool is pushed forward. The preferred method of filing is to raise the file from the work before drawing it back to start the next stroke. Only enough pressure should be applied to the file to keep it cutting. Excess pressure only results in increased effort being required to move the file forward.

File teeth will tend to become clogged, particularly when soft metals are being filed, and material between the file teeth will tend to scratch the surface being filed. This can be overcome to a degree by first rubbing chalk on the file.

After use, clean the teeth of the file by brushing with a "file card" or other wire brush. Files should be hung on a rack when not in use, as placing them in a drawer with other tools will quickly dull the teeth.

SOLDERING

Soldering is a method of joining two metals together, one of the major uses being to connect electrical wiring to instruments and other electrical equipment. This keeps the wires from becoming loose or disconnected, as the result of vibration.

The process of soldering consists of first cleaning the surfaces to be joined. The joint is then heated and a flux, which is a chemical designed to keep oxides from forming and permit the solder to adhere to the surfaces, is applied. The solder, an alloy of lead and tin, is then melted into the joint, by means of a soldering copper or the flame of a torch. By varying the proportions of the lead and tin, solder of different melting points can be secured. Solders that melt readily are known as soft solder, while those which require greater heat are known as hard solder.

Soldering coppers (more often called irons) are used mostly for soldering small pieces or when there is a danger of an open flame damaging nearby parts. Made of copper, the tips of these tools must be given a coating of solder before they are used. This is known as tinning. The process is to first file the tip of the copper so that it is clean and smooth. It is then heated, dipped in flux and solder applied. After the iron has been tinned, it should not be overheated, as the copper would burn off and retinning would be required.

On some soldering jobs, it is desirable to first tin the surfaces to be joined, and then solder them together. That process is usually followed on larger areas

where a strong joint is required. It is also used when solder is to be applied to sheet iron.

When tinning, some mechanics prefer to melt the solder on the surface of a building brick, and then rub the tip of the copper on the solder. Another method is to use a block of sal ammonia.

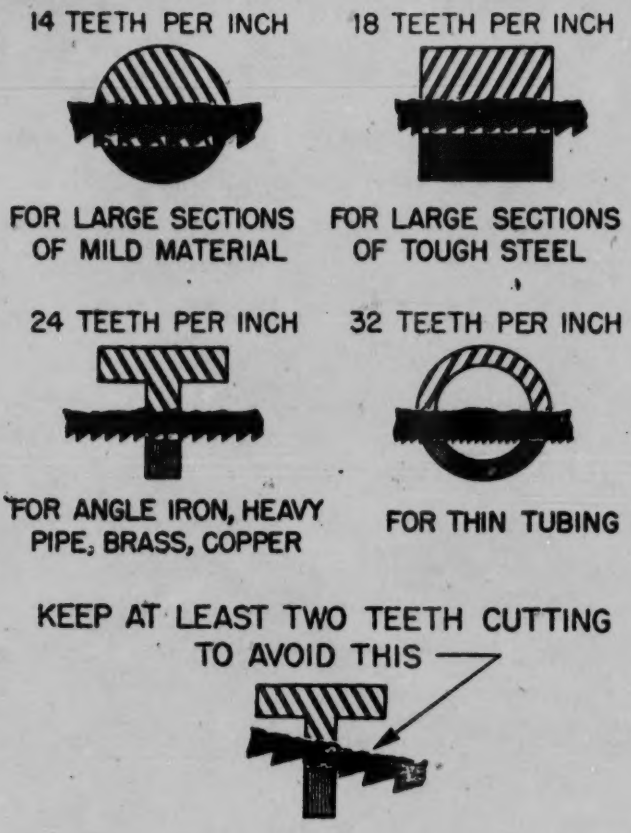
Soldering coppers may be heated in a flame or special cover, or may have built-in electric heating elements.

There are many different types of fluxes available. It is important to select the type best suited for the metals to be joined. For electrical connections a rosin-type flux is recommended. An acid-type flux is used when soldering sheet iron.

HACK SAW

Hack saws are used to cut metal. The detachable cutting blade is mounted in a metal frame. Different length frames are available, or are made adjustable so that various size blades can be used. The usual lengths of hack saw blades are 8, 10, and 12 in. The 10 in. and 12 in. sizes are most frequently used. For power-driven hack saws, blades of 12, 14, 17, 18, 21, 24 and 30 in. lengths are available.

Hack saw blades are made of high grade tool steel, hardened and tempered. There are two types, the all-hard and the flexible. All-hard blades are hardened throughout, while only the teeth of flexible blades are hardened. In general, an all-hard blade is considered best for sawing brass, cast-iron, steel and other stock of heavy cross section. For cutting hollow shapes, and metals of light section such as channel iron, tubing tin, copper, aluminum or babbitt, a flexible blade is preferable.


14 TEETH PER INCH
18 TEETH PER INCH
FOR LARGE SECTIONS OF MILD MATERIAL
FOR LARGE SECTIONS OF TOUGH STEEL
24 TEETH PER INCH
32 TEETH PER INCH
FOR ANGLE IRON, HEAVY PIPE, BRASS, COPPER
FOR THIN TUBING
KEEP AT LEAST TWO TEETH CUTTING TO AVOID THIS

How to hold a hack-saw, keeping the blade at right angles to the work. The pressure on the saw should be relieved on the return stroke.

Figure 1-5 Hacksaws

Blades for hand-operated hack saws come with 14, 18, 24 and 32 teeth per inch. It is important that the teeth per inch be considered when selecting a hack saw blade for a particular job, Figure 1- 5. Thought must be also given to whether the all-hard or flexible blade is more suitable for a particular job.

Hack saw blade manufacturers recommend that 14-tooth saws be used for cutting soft steel, brass, cast-iron and stock of heavy cross section. For cutting drill rod, light angles, high speed steel, tool steel and small solids, 18-tooth blades are recommended. Use 24-tooth blades for cutting brass tubing, heavy B-X cable, iron pipe, metal conduit and drill rod. For cutting thin tubing, sheet metal, light B-X cable, channels, etc., 32-tooth blades are suggested.

After selecting the correct blade for the material it is attached to the frame by inserting the pins of the frame in the holes at the ends of the blade. To adjust the tension of the blade, and also to secure it tightly to the frame, the position of one of the pins is adjustable, by either a wing nut or by turning the handle.

The "set" in a saw refers to the amount the teeth are pushed out in opposite directions from the sides of the blade. The teeth of all hack saw blades are set to provide clearance for the blade.

If an accurate cut is to be made, it is advisable to mark the stock with a scriber, and nick the work with a file. The nick will make it easier for the saw to start cutting and also ensure accuracy. The work is then placed securely in a vise, with the line to be cut as close to the vise jaws as possible. Use sufficient pressure on the saw when starting the cut, so that the saw teeth immediately

begin to bite into the metal. The hack saw blade should be held horizontally and moved forward with a light steady stroke. At the end of the forward stroke, relieve the pressure and draw the saw straight back.

The most effective cutting speed is about one stroke per second. When the material is nearly cut through, the pressure on the blade should be reduced to prevent the teeth from catching. When cutting thin stock, it is advisable to clamp it between two pieces of wood or soft metal, and saw through all three pieces. This will prevent the saw from sticking, and also prevent possible damage to the work.

For cutting round holes in metal, a circular saw is advisable. The circular saw is driven by an electric drill, and is used for drilling large diameter holes in instrument panels for the installation of instruments and other accessories. It is provided with a centering or pilot drill for starting and centering the cut.

DRILLING

General

Frequently it is necessary to drill holes in order to install additional accessories and equipment. While holes are occasionally drilled with a hand or breast drill, the usual method is to use an electric drill. The electric drills most commonly used are 1/4 in., 1/2 in., and 3/4 in. The size designations indicate the largest size drill that should be inserted in the chuck. If drills larger than the specified size are used, the electric drill will be overloaded and will overheat. Premature failure can then be expected. It should be pointed out, however, that a well-made electric drill can stand a certain degree of overload for a short period without harm.

Twist Drills

The tool used to do the actual cutting is known as a twist drill. A twist drill has two cutting edges and are made of either carbon steel, or high speed steel. Carbon steel quickly becomes dull and if heated excessively, it will lose its hardness. High speed steel will retain its temper when red hot and twist drills of that material are therefore preferred.

While there are other types of drills, the straight shank drill is used almost entirely in hand drills.

Sharpening Drills

Before a drill is used, it is important that it be correctly ground and sharpened. Unless the drill is in good condition it may drill an oversize hole, possibly break or at least cut slowly. A correctly sharpened drill will have:

1. equal and correctly sized drill point angles;

2. equal length cutting lips;

3. correct clearance behind the cutting lips, and

4. correct chisel edge angle

All four are equally important and are illustrated in Figure 1-6.

For general drilling, the angles shown in the upper part of Figure 1-6 are used, while if very hard and tough materials are to be drilled the angles shown in the center center

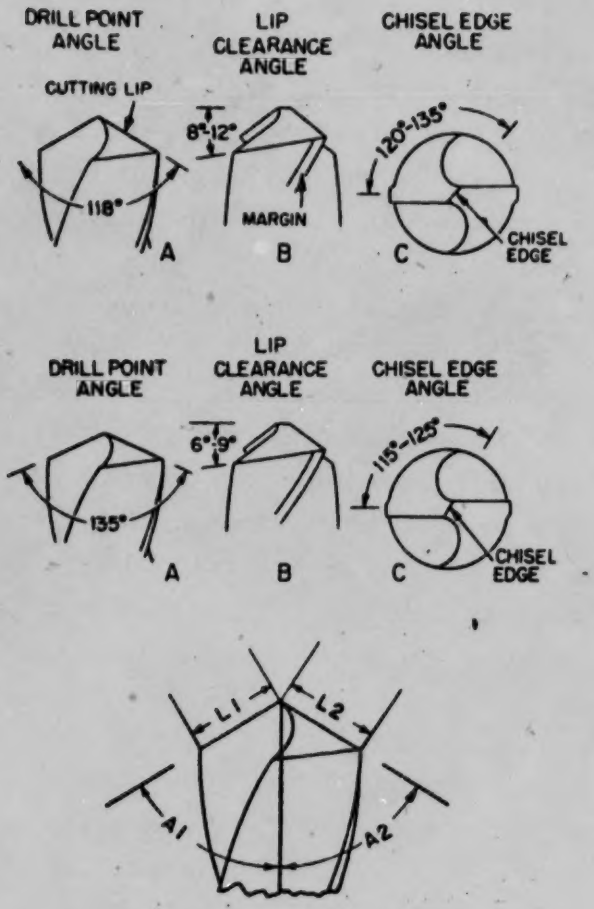


Figure 1-6 Angles on a Twist Drill

of the illustration are used. The lower portion of the illustration shows what is meant by the two halves, A-1 and A-2 of the drill point angle, as well as the two equal-length cutting lips, L-1 and L-2.

Lip clearance behind the cutting lip at the margin is determined by inspection, while the cutting edge or lip within certain limits, as shown in Figure 1-6, but must be the same on both sides of the drill. The margin, shown at the top of Figure 1-6, is the narrow strip which extends the entire length of the flutes, and is practically the full diameter of the drill. The portion back of the margin is slightly less in diameter and is the body clearance.

Both lips of a twist drill must be the same length. For most materials they should be ground to an angle of 59 degrees. If the cutting edges are ground at different angles, and the point is in the center, only one lip will cut. The angle of 59 degrees for the lip is correct when the drill is to be used on aluminum, steel and cast-iron. For brass and copper the angle should be 50 degrees; while 45 degrees is preferred for Bakelite, plastic, wood or fibre.

The heel of the drill, that is the surface of the point back of the cutting lips, should be at an angle of 12 to 15 degrees, as shown in Figure 1-6. Incorrect grinding of the lip clearance will result in drilling holes larger than the diameter of the drill, drill breakage and slow cutting.

The rake angle of the drill is the angle of the flutes in relation to the axis. This is usually 22 to 30 degrees, and is of course built into the drill by the manufacturers.

To ensure accuracy, drills should be placed in a grinding jig or attachment for sharpening.

REAMERS

When it is desired to have a hole with particularly smooth surface or have the hole finished to an exact diameter, a reamer, Figure 1-7, should be used. The hole is first drilled to a diameter slightly smaller than that desired and then enlarged to the required size with the reamer.

A reamer consists of three parts, the body, shank and cutting blades. The blades of a reamer are made of steel, and hardened to such an extent that they are extremely brittle. They must, therefore, be carefully handled. Only a very little metal should be removed by the reamer, as it is a finishing operation and it is not designed to make heavy cuts. Usually .002 in. is the limit of the amount of metal to be removed by reaming. To protect reamers, the usual method of storing is to provide a wooden rack with a separate division for each reamer.

When reaming a hole, the reamer should be turned in the cutting direction only. It can be rotated by hand, with a suitable wrench or handle, or it can be power driven. When power driven, the speed is approximately 50 rpm. By steady even rotation of the reamer, "chattering" is reduced or eliminated.

Figure 1-7 shows two solid reamers, a spiral flute reamer, and a straight flute reamer. The spiral flute is more expensive but has a reduced tendency toward chattering. Reamers of the types shown are available in standard sizes and are also available in size variations of .001 in. for special work.

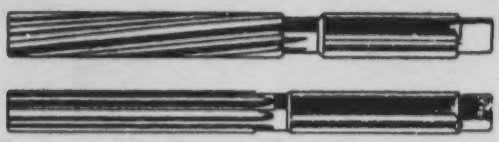


Figure 1-7 Reamers Upper - Spiral Flute
Lower - Straight Flute

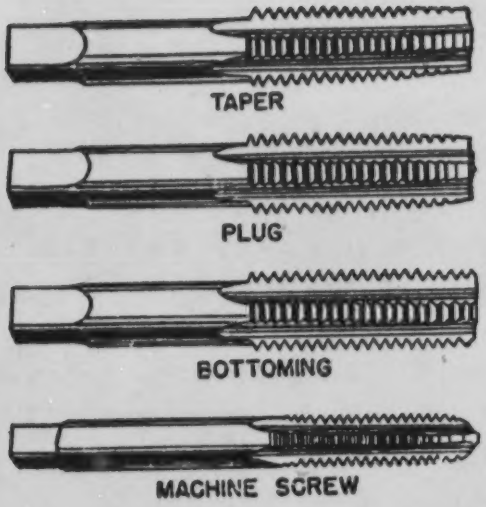


Figure 1-8 Taps

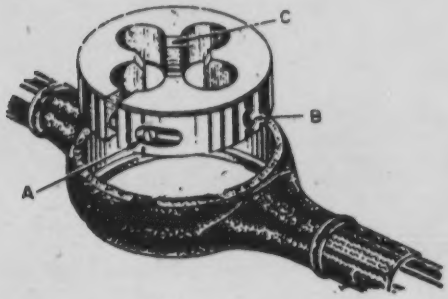


Figure 1-9 Adjustable Round Split Die
A - Adjusting Screw
B - Drive Hole
C - Cutting Teeth

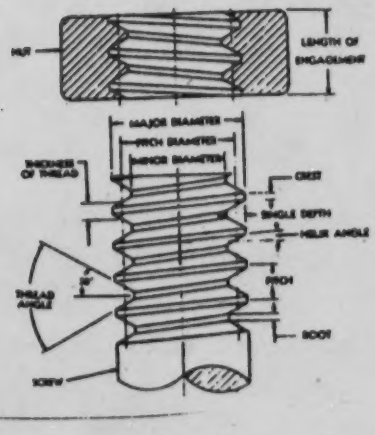


Figure 1-10 American Standard Screw Thread Terms

Where only occasional reaming is to be done, it is more economical to have expansion or adjustable reamers, embracing the required range of sizes. Care must of course be taken when adjusting the size of the reamer, to be sure it is correctly set. In setting adjustable reamers, the usual method is to use a micrometer.

Expansion reamers are usually available in standard sizes from 1/4 in. to 1 in. by 32nds. They are designed to allow the blades to expand 1/32 in. For example, the 1.4 in. expansion reamers will cover sizes ranging from 1.4 in. to 9/32 in.

TAPS AND DIES

Taps, Figure 1-8, and dies, Figure 1-9, are thread-cutting tools. A tap is used to cut internal threads on such parts as nuts, while a die cuts external threads on bolts and studs.

There is special terminology used when describing threads, bolts and nuts, Figure 1-10. To avoid confusion when discussing taps and dies, it is important that such terms be understood.

The major diameter, formerly known as the outside diameter, is the largest diameter of the thread. The minor diameter is the diameter taken at the base of the thread. The pitch of a thread is the distance measured parallel to its axis, between corresponding points on adjacent thread forms, in the same axial plane and on the same side of the axis. The number of threads per inch (TPI) is the reciprocal of the pitch in inches, e.g. 4TPI = 1/4 pitch.

When it is desired to drill and tap a hole, the hole must be of the correct diameter for the particular tap. That is known as the tap drill. The different tap and drill

Nominal size	Thr'd series	Major diameter, inches	Root diameter, inches	Tap drill to produce approx. 75% full thread	Decimal equivalent of tap drill
0–80	N. F.	.0600	.0438	3/64	.0469
1–64	N. C.	.0730	.0527	53	.0595
72	N. F.	.0730	.0550	53	.0595
2–56	N. C.	.0860	.0628	50	.0700
64	N. F.	.0860	.0657	50	.0700
3–48	N. C.	.0990	.0719	47	.0785
56	N. F.	.0990	.0758	45	.0820
4–40	N. C.	.1120	.0795	43	.0890
48	N. F.	.1120	.0849	42	.0935
5–40	N. C.	.1250	.0925	38	.1015
44	N. F.	.1250	.0955	37	.1040
6–32	N. C.	.1380	.0974	36	.1065
40	N. F.	.1380	.1055	33	.1130
8–32	N. C.	.1640	.1234	29	.1360
36	N. F.	.1640	.1279	29	.1360
10–24	N. C.	.1900	.1359	25	.1495
32	N. F.	.1900	.1494	21	.1590
12–24	N. C.	.2160	.1619	16	.1770
28	N. F.	.2160	.1696	14	.1820
1/4–20	N. C.	.2500	.1850	7	.2010
28	N. F.	.2500	.2036	3	.2130
5/16–18	N. C.	.3125	.2403	F	.2570
24	N. F.	.3125	.2584	I	.2720
3/8–16	N. C.	.3750	.2938	5/16	.3125
24	N. F.	.3750	.3209	Q	.3320
7/16–14	N. C.	.4375	.3447	U	.3680
20	N. F.	.4375	.3726	25/64	.3906
1/2–13	N. C.	.5000	.4001	27/64	.4219
20	N. F.	.5000	.4351	29/64	.4531
9/16–12	N. C.	.5625	.4542	29/64	.4844
18	N. F.	.5625	.4903	31/64	.5156
5/8–11	N. C.	.6250	.5069	33/64	.5312
18	N. F.	.6250	.5528	35/64	.5781
3/4–10	N. C.	.7500	.6201	41/64	.6562
16	N. F.	.7500	.6688	11/16	.6875
3/4–9	N. C.	.8750	.7307	49/64	.7656
14	N. F.	.8750	.7822	25/32	.8125
1–8	N. C.	1.0000	8376	7/8	.8750
14	N. F.	1.0000	9072	15/16	.9375

Figure 1-11 Table of Thread Sizes, together with Tap Drill and Clearance Drill Sizes

sizes are given in Figure 1-11.

When it is desired to drill a hole into which a bolt is to be inserted, the drill is known as a clearance or body drill.

Taps and dies are marked according to the type and diameter thread they will cut. For example, an 8-32 is designed to cut 32 threads per inch on No. 8 stock.

When tapping a hole with a tap or cutting a thread with a die, considerable care is required. Taps are easily broken. When using a tap or die, it is important that the direction the tool is turned be reversed frequently. This is done to free the tool of chips and also recut the threads. Forcing the tool will result in tool breakage, ruined parts and poor threads.

When threading steel parts a cutting oil should be used. Kerosene is preferred for use with aluminum. No lubricant is required for threading brass or cast iron.

FABRICATED TUBING

Fabricated tubing is used extensively for oil and fuel lines. Great care must be exercised in fitting tubing for specific jobs. The selection of the wrong material, may result in accidents. Soft copper tubing is usually considered satisfactory for fuel lines. As it is not strong enough to withstand the pressures developed in hydraulic lines, seamless steel tubing is used for this purpose.

Dimensions of copper and steel tubing are given in Table 1-1. Note that the outside diameter of tubing is used to indicate its size, whereas pipe sizes are determined by their inside diameter.

TABLE 1-1

Dimensions of Copper and Steel Tubing

Size or O.D.	Wall Thickness Copper Tube	Wall Thickness Single Wall Steel Tubing	Wall Thickness Double Wall Steel Tubing
1/8	.030	.025	.025
3/16	.030	.025	.025
1/4	.030	.028	.028
5/16	.032	.028	.028
3/8	.032	.028	.028
7/16		.030	.032
1/2	.032	.030	
1/2		.035	
9/16		.030	
5/8	.035	.035	.035

When installing a line of tubing the first step, after selecting the size and material of which the line is to be made, is to cut it to the length desired. Only a special tubing cutter should be used, as it is imperative that the tubing be cut smoothly and at right angles to the center line of the tubing or it will be impossible to make a leak-proof joint.

A tube cutting tool will make a clean cut, square with the sides of the tubing. In addition, there is no possibility of filings getting into the tubing, and subsequently causing trouble in the system. With a tubing cutter the position of the cutting wheel is asjusted until it contacts the surface lightly. The complete tool is then swung completely around the tubing, after which the cutting wheel is again adjusted. The procedure is repeated until the cut is completed.

After the tubing has been cut to the desired length, the ends should be reamed or burred to remove any burrs at the end of the tubing. One method of doing this is to use the reamer provided on one end of the tubing cutter. When reaming tubing, it is always important to hold the end of the tubing pointed down, so metal chips will not drop into the tubing.

One type of reaming tool is an "inner and outer" reamer. This is a cylindrically shaped tool that reams both the inside and outside edges of the tubing.

With the tubing cleanly and squarely cut, reamed and with burrs removed, it is then ready for either a tight joint with a compression (flareless) type fitting or use with a flared-type fitting.

The flareless-type fitting is known as a compression fitting, and requires only that the end of the tubing be smooth and true. The connection can be quickly made, but has the disadvantage that it cannot be taken apart many times without the probability of leaks occurring.

The flare-type connection, as the name implies, requires that the end of the tubing be flared. This type of fitting can disassembled many times with but little possibility of leaks occurring.

FLARING

There are several different types of flaring tools available. One type consists of a flaring bar and screw feed flaring yoke. When making a flare with a tool of this

type, the tubing is placed in the flaring bar with the end protruding slightly above the face of the bar. Care must be taken that the tubing is clamped in the bar, so pressure of the flaring cone will not force the tubing through the bar.

Before slipping the yoke over the bar to start flaring, a little oil should be placed on the cone or spreader. Particular care must be taken when the flared connection is to be used on units subject to vibration. It is not wise to work the tubing any more than is necessary, because this will tend to make the metal hard and brittle and more likely to break.

On tubes flared too short, the full clamping area of the fitting is not used and consequently the joint may leak or suffer early failure. Tubing flared too long will stick and jam on the threads during assembly. Flares that are not straight usually result from the fact that the tubing was cut on an angle.

It is frequently necessary to bend tubing. This should be done only with special tube benders but only soft temper tubing should be bent. On smaller size tubing, a simple outside bending spring is usually satisfactory. This bender is slipped over the outside of the tubing and prevents the tubing from kinking when it is bent. When using a spring-type tube bender, it must be remembered that the tubing must be bent somewhat further than required, and then backed up to the desired angle. In that way the spring is loosened in the bender and can be easily removed.

On larger sizes of tubing or where precise and uniform bends are required, the use of a lever-type or gear-type bender should be used. These benders can be slipped on the tubing at the exact point the bend is desired, and are particularly advantageous when the tubing has been partly connected, or is located in hard-to-get-at places. Bulk tubing is sold in coils. When removing a piece of copper tubing from a coil, first place the coil on the bench. Hold down the free end of the tubing, and then roll the coil of tubing along the bench until the desired length is obtained. In this way kinking the tubing will be avoided.

DIVIDERS

Description

The divider has hardened slender and sharp steel points and is used for scribing circles and laying off distances, Figure 1-10. It is adjustable and is classified according to size by the maximum opening between the points, which varies in size from 2 1/2 inches to 12 inches. Those illustrated here are known as Spring Dividers deriving the name from the stiff, flat bow spring in the head. Dividers are made with a solid nut for making adjustments and also with a "Quick" nut. The quick nut slides freely over the threads of the screw when the pressure is released, but grips the screw firmly on the least leg pressure.

The points of the dividers and the threads on the adjusting screw must be protected if the tool is to give good service.

Use of Dividers

To take a dimension from a scale (rule) place one point on a convenient dimension line, and adjust the other leg until it exactly splits the graduation line the correct distance away. Since the scale graduations are V-shaped it may be easier to feel the correct position than see it. On precision work a magnifying glass will help greatly.

The divider can be used to scribe a circle on a metal block or plate. Having located the centre of the circle make a slight indentation with a prick punch, by striking a light blow with the machinist hammer. Then set the divider to the required measurement of the radius of the circle, place one point of the divider in the centre punch mark and scribe the circle using a pressure on the other point just sufficient to make a visible continuous line. It may be used in much the same way to lay off distances or parallel lines.

CALIPERS

Description

A caliper is a tool used in measuring inside and outside diameters. It is used with a steel scale and at times with a micrometer, especially in the machinist trade. They are known as Outside and Inside Calipers.

There are two styles that the tradesman may acquire. The Firm Joint Calipers are shown in Figure 1-12. Lock screw construction enables us to set and hold the legs to any desired tension or friction. The main hinge stud is

squared and fitted to one leg, thus preventing the stud from turning when loosening and tightening, and ensuring a smooth and uniform friction. They are made in various sizes from 3 inches up to about 36 inches. The spring calipers are built like the spring dividers and will not be described here.

Calipers should receive the same care and attention given to other instruments. They are used as measuring tools where great accuracy is not essential; and they may be used as a gauge.

Use of Calipers

When used as a measuring tool, they are adjusted to the size of the object for which the dimension is required. The beginner will need some practice in making accurate adjustments. The outside caliper should be adjusted till it will barely hang from the work without falling off. It is possible to force calipers over the work which introduces an error. In making this adjustment the axis of the caliper should be perpendicular to the axis of the work.

When adjusting the inside caliper, the axis of the caliper should coincide with the axis on the work.

Reading An Outside Caliper

Having adjusted an outside caliper to an object, we need to determine the exact size of that object. Hold the scale in the left hand with the low reading and against the little finger. Hold the caliper in the right hand so that the point of one leg rests on the little finger and against the end of the scale. The other leg rests against the scale; and the dimension is read at the graduation just showing under the point.

It may be necessary to use an edge of the rule with finer graduations if more accuracy is required.

Reading A Inside Caliper

Having adjusted the inside caliper to an inside diameter, the rule and the one caliper leg may rest on a smooth flat surface approximately level with the eye and in good light. The reading is taken at the graduation just showing under the point of the uppermost leg of the caliper.

Using the calipers as a gauge the process is reversed. Measurements are taken off a scale and applied to an object.

If Spring Calipers are being used the nut is adjusted by the thumb and forefinger of the right hand.

However, if Firm Joint Calipers are being used adjustments are made by rapping one leg of the caliper lightly against some solid object.

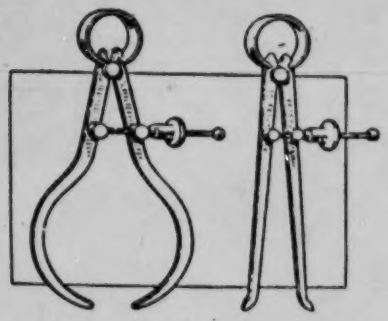
Hermaphrodite Calipers

Hermaphrodite calipers are made with two legs; one blunt and curved at one end, the other with a scriber point (Figure 1-12). The scriber point is usually adjustable so that it can be adjusted for length when the curved leg is resting on an outer edge.

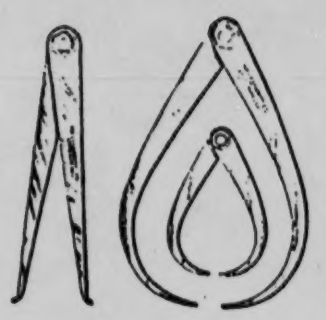
It is used for locating centers of round pieces, centers of bosses, etc. It may also be used to scribe a line or to locate a point parallel with a surface or shoulder.

THE COMBINATION SET (SQUARE)

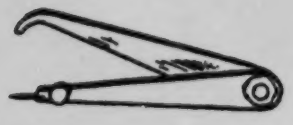
The set consists of a steel rule (blade) on which slide the centre head, protractor head and the square head shown in this order in Figure 1-13. The blade can be used alone or in combination with one or more heads. The heads can be clamped at any point on the blade by tightening a clamping nut.



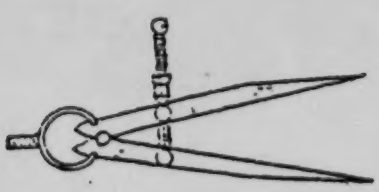
Outside and Inside
Spring-Bow Calipers



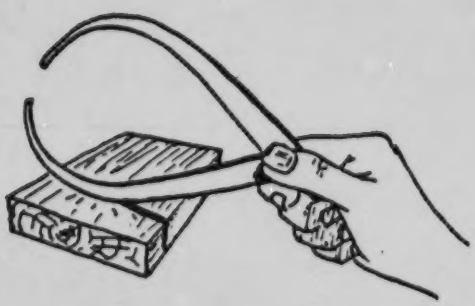
Firm Joint Calipers



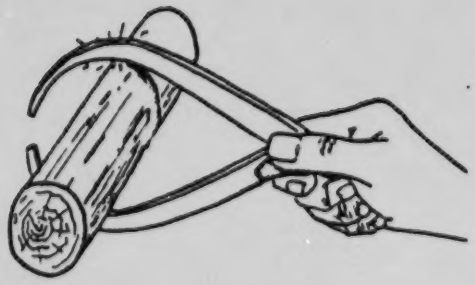
Hermaphrodite Calipers



Dividers

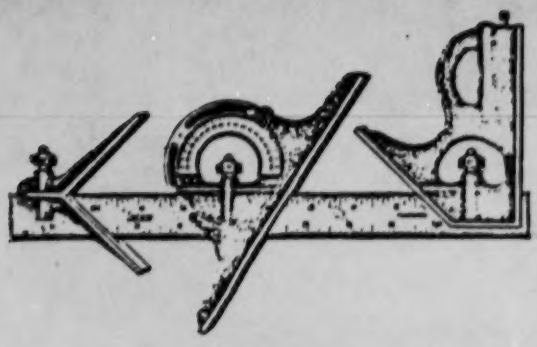


Closing Firm Joint Calipers



Opening Firm Joint Calipers

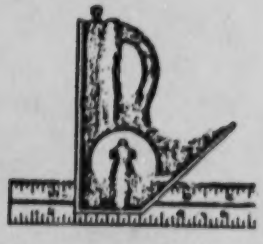
Figure 1-12 Calipers, Dividers



Combination Set Square

Centre Head Square

Bevel Protractor Head Square



Square Head Square

Figure 1-13 Set Squares

1. The blade is made with a groove on one side on which travels a guide in the heads. Blades are made with different graduations (8ths, 16ths, and 32nds, and 64ths) on the edges. They come in lengths 4, 6, 9, 12, 18, and 24 in.

2. The centre head, Figure 1-13, is referred to sometimes as a centre square. The arms of the head are precision ground to form a square. They are cast, or drop forged and hardened.

3. The Bevel Protractor head, Figure 1-13, is provided with a swivel or turret to which the steel rule is clamped. The revolving turret is graduated in degrees from 0 to 180, or from 0 to 90 degrees in either direction. It can be adjusted to a specific angle and clamped in position with a knurled nut. Some heads are equipped with a level glass.

4. The square head, Figure 1-13, is built with a level and a mitre (45 degrees). As with the other heads the square head can be clamped to the blade in any position along the rule. It is also provided with a scriber. The scriber is a piece of tool steel, usually drillrod, about 1/8" in diameter, 3 1/2 inches long and tapered at one end to a needle point. It is hardened and tempered.

Care and Uses of Set Squares

The greatest care should be exercised in handling, using and storing this useful tool. Properly used it will save littering up the bench with a number of tools, since the set combines a rule, square, mitre, depth gauge, height gauge, level, and centre head.

Only a few of the jobs can be indicated here. The square head adjusted flush with the rule becomes a try square and a height gauge; adjusted to a reading on the rule it becomes a depth gauge. It can also be used to scribe vertical and horizontal lines. The centre head clamped to the rule (or blade) can be placed against round stock, and a line scribed along the edge of the blade or rule will pass through the axis of the round. This process repeated at approximately 90° will locate the centre of the round where the scribed lines cross. The protractor head can be accurately adjusted to show any angle and to transfer it to other objects. Where it is desirable to measure an angle the base of the protractor is placed against one side of the work and the blade adjusted to rest against the other side of the work. The clamping screw is tightened and the angle is read in degrees on the graduated face of the turret face at the index line.

The scriber is used to mark lines on metal surfaces which have been prepared with chalk or blue vitriol. Chalk rubbed into a metal surface will help to make a scribed line clear and distinct. To make lines more distinct on a finished surface rub the surface with a piece of waste dipped in blue vitriol solution. This solution is made by dissolving a small handful of copper sulphate into a half pint of water and a few drops of nitric acid are added. The solution should be kept in a wide-neck bottle or jar.

When the point of the scriber becomes dulled, sharpen it on an oil stone by rotating the scriber between the thumb and forefinger while moving it back and forth.

In scribing keep the point of the scriber close to the rule or other guide and incline in the direction in which it is to be moved.

APPENDIX A

TOOLS USED FOR MAINTENANCE IN AN AVERAGE SIZE TREATMENT PLANT

500 volt Megger
Amp-Probe Model - RS - 3 RS1007S
½" Drive Socket Set 3/8" - 1¼"
7" Vise Grips
Combination Wrench Set 3/8" - 1¼"
10" Vise Grips
pr. 7" Long-Nose Plier
pr. 7" Diagonal Cutter
pr. 6" Bent Nose Plier
pr. 10" Channel Lock Plier
pr. 8" Line-Man's Plier
Set of Flat Screw-Driver
Nylon Starter Screw-Driver
Phillips Screw-driver Set
Set of Spinner Wrenches ¼" - ½"
Punch and Chisel Set
Set Long Handle Allen Wrench .050" - 3/8"
Set Short Handled Allen Wrench .050 - 3/8"
Tubular Hacksaw Frame
10" x 18T STD. Hacksaw Blades
8" Adjustable Wrench
10" Adjustable Wrench
Set Feeler Gauges .0015" - .035"
Flaring Tool 3/16" - 5/8"
Tube Cutter 1/8" - 1"
Three-leg Pullers
Soft Face Hammer
8 oz. Ball Peen Hammer
3 lb. Ball Peen Hammer
16 oz. Ball Peen Hammer
2 lb. Ball Peen Hammer
1½ lb. Ball Peen Hammer
pr. Circular Pattern Snips

Set Thread Restorer Nuts ¼" - 5/8" N.C.

Tool-Box with Tote Tray 19" x 7" x 7"

6" Spring-Dividers

6" Spring Outside Calipers

6" Spring Inside Calipers

½" x 10' White Face Tape

½" x 50' White Face Tape

24" Pipe Wrench

18" Pipe Wrench

10" Pipe Wrench

6" 'C' Clamps

4" 'C' Clamps

½ Reversible Drill Electric

3/8" Vari-Speed Drill Electric

6" Bench Grinder

Set in Box 1/16" - ½" x 1/64 increase
High Speed Twist Drills

4" Jaw Adjustable Bench Vise

25' Extension Cord with Ground Wire

25' Trouble Lamp

Heavy-Duty Weller Soldering Gun

Hand Propane Torch Kit in Carry Case

26" x 8 pt. Hand Saw

1 lb. Steel Shafted Claw Hammer

6 lb. Sledge Hammer

Set of Fibre Fuse Pullers

½" Screw Shackles

4 ft. Nylon Slings

Endless 8 ft. Nylon Slings

Crow Bar

Floor Model ½" Drill Press and ½ Hp. Motor Man. Switch

3" Jaw for Drill Press Machine Vise

Set Oxygen and Acetylene Outfit

½ Ton Electric Hoist Mod. F. 30' Lift 100 volt

1 pr. 16-10 Wire Stripper

Inspection Mirror

Magnetic Pick-Up Flexible

Circular Hand Saw 7¼'

Set of Bearing Pullers Complete with Bearing
Splitter Plate

3/4/ Ton 6' Lift Lever operated Hoist	
3 Ton Hydraulic Jack	
Ignition Wrench Set	
115 - 220 V 7-8 HP Gas Engine Generator Set	
Power Feed Rodding Equipment	For WPCP's with responsibility for collector systems.
Brushless Air Blower 450 C.F.M. with 30' of 8" Hose	
Sewer Steel Tape 1/8" x 75'	
Revolving Swivel Head	
3/4/" Revolving Spearfin Head	
3/4 HP Electric Air Compressor	
8 gal. Wet & Dry Vacuum Cleaner	

SUBJECT:

PREVENTIVE MAINTENANCE

TOPIC: 2

UTILIZATION OF DRAWINGS AND EQUIPMENT MANUALS

OBJECTIVES:

The trainee will be able to:

1. Recall general information available in the manufacturer's equipment manual.

2. List the important factors found under the following categories in an equipment manual:

   (a) Identification of the unit and supplier.

   (b) Installation procedures.

   (c) Start-up procedures.

   (d) Operation and maintenance.

   (e) Trouble shooting.

   (f) Service and repair.

3. Recall the use of electrical and piping symbols used on schematics.

4. Read plans by use of the front view, side view, top view and sectional.

5. Interpret the legend on drawings including the unit of measurement and the graphic symbols.

6. Demonstrate the use of:

   (a) construction drawings

   (b) mechanical drawings.

UTILIZATION OF DRAWINGS AND EQUIPMENT MANUALS

INTRODUCTION

An operator may be confronted with the need to examine drawings of his plant. If he has a broken pipe and has to locate it, memory may fail where an accurate set of drawings, IF AVAILABLE, will provide him with the shortest and most economic distance between him and the problem. He can learn location, depth, type, size and perhaps a clue to his problem because of the configuration of the original installation. When a plant is being expanded, the operators' opinion on directional flow, type of valve required or other operating criteria may be asked for. At the drawing stage is the time to voice opinions. After that one may be stuck with a problem, one that an operations person would appreciate at the drawing stage and could have eliminated before it became an expensive and troublesome fact.

Further, where are the instruction manuals for the plant equipment? Is memory serving as the guide to schedules for oiling and greasing equipments? Can parts which need replacing, and the supplier of the original material be easily identified? How often is a new piece of equipment installed and put into operation according to the manufacturer's startup procedures? Is the instruction manual used or is it filed and forgotten? Proper use of the equipment manual will ensure satisfactory operation as well as preserve the integrity of the manufacturer's warranty.

This topic will discuss the information available from drawings, manuals and other reference material and the importance of making use of these sources.

EQUIPMENT MANUALS

Accessibility

Where are the equipment manuals? If they are not readily available, one of the most useful tools in plant operation is lost. First of all, locate a manual if one is printed for each piece of equipment in the plant. This may require searching through piles of debris or sending to a manufacturer requesting its replacement. In any case, obtain them and *file them by some orderly system* so that when one is required it is available.

An equipment manual is a textbook on the equipment one depends on to produce a satisfactory product. If the fundamental requirements for the operation of a piece of equipment are known, a basis for its proper care is established. The use of this information coupled with operating experience should provide high quality maintenance control.

An equipment manual can offer information on:

1. Identification of the unit and supplier
2. Installation
3. Start up
4. Operation and maintenance
5. Trouble shooting
6. Service and repair

Identification of a piece of Equipment and its Supplier

Check the equipment and manual to be sure that they match. Establish from the manual exactly what the machine is supposed to do. Does it meet the need? Are the operating conditions/requirements according to the manual amenable to the equipment's condition, operation or is the pump or compressor incapable of performing under all situations?

Not only determine what the equipment does, but the basic principle behind its operation. Often a manual will describe this either in general or in detail. For example Appendix A includes the general information on a non-clog pump and Appendix B detailed description of a standby diesel power supply. With some of the mystery surrounding a piece of equipment removed, it can be more easily operated and serviced.

Installation

Minor pieces of equipment can malfunction as easily as major ones. When a replacement for a pump is required the reasons for the failure of the original equipment should be examined. Was it caused by the site location or the way it was secured? Was it caused because the recommended procedure from the manual is wrong or was not followed? Were short cuts taken during installation? Know what is involved from foundation to securing requirements to ensure that the installation is according to design. It will save a lot of grief, time and money if installation is correct from the start.

Start Up

Even if a new pump is properly installed it is important that the manufacturer's start-up and operating procedures be followed. If, due to local conditions, it is not possible to adhere to the manufacturer's instructions, it would be advisable to obtain the manufacturer's written approval of the amended procedures. Failure to do so may, in the event of trouble, invalidate the warranty. *Always use the manufacturer's startup check list.*

Operation and Maintenance

Now that the pump is operating, a preventive maintenance program must be established. The manual recommends the types of oil and grease to be used. It should indicate acceptable packing and the method of installation; or for mechanical seals, frequency of cleaning the filter and even seal replacement. Time periods (or signs to look for) may be indicated when a maintenance job is required. All this information may be summarized and put into a regular operation schedule so that no standard check is missed which would result in costly and serious damage. Carry out the checks required by the manual or as experience dictates, whichever is the most frequent. This is particularly significant immediately after the equipment goes into operation when it is assumed to be operating properly but when no check is required by the schedule.

Troubleshooting

Assume something has failed and now the wet well is three quarters full and rising fast. What is wrong with the unit - can it be easily corrected? The general consensus from the operating personnel is "I don't know what happened". *Refer to the manual.* Often a piece of equipment will give a clue to its problem just before break-down; such as lower volume delivery, high or low r.p.m. or frequently going out on its breakers. Hopefully an operator will observe any changes in equipment operation and will attempt to isolate the cause through the troubleshooting aids before serious breakdown occurs. The section of the manufacturer's manual on troubleshooting will provide a solution sine it is based on many years of experience.

Service and Repair

The manual will provide considerable information for service and repair of the equipment. Often, detailed drawings will be present indicating specific parts for ease of identification in ordering from the supplier. Frequently, drawings may be general drawings and represent several models of the same design. Be certain the model and serial number is obtained directly from the unit so that the correct section of the manual is used for obtaining the required information. Details of areas of frequent repair may be covered thus providing a list of replacement parts, to be kept in stock. This can offer the advantage of minimizing the down time of the equipment.

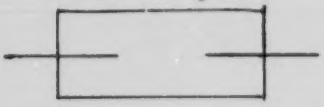
SYMBOLS

A symbol is a standard diagrammatic representation of a piece of equipment. Its purpose is to simplify the illustration of the components in a drawing and still indicate accurately the components purpose.

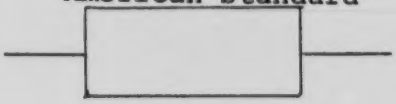
On the following pages are copies of standard electronic symbols (Fig. 2-1) and piping symbols (Fig. 2-2, 2-3). Significantly, however, everyone does not follow the same standard. For example, Ontario Hydro single line symbols are compared with those found in the American Standard examples:

1) Joint Expansion

Ontario Hydro

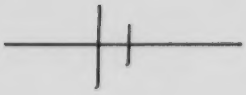


American Standard



2) Gate Valve

3) Bushing



Note the American Standard symbols also denote screw type as opposed to flange, bell and spigot, welded or soldered. A symbol can demonstrate what it is and how it is assembled. One should determine just what set of standards are being viewed to fully appreciate what is observed.

The symbol used by Ontario Hydro to represent a Gate Valve is the same as the symbol used in American Standard drawing practice. However, even though this similarity will occur throughout the conventions for single line fittings and valves, beware of the exception. When reading diagrams or drawings constantly refer to the legend which has been provided by the draftsman. In the absence of a legend, and whenever there is room for doubt or confusion, the draftsman will provide a description of the item.
Fig. 2-2 illustrates the single line conventions for fittings and valves.

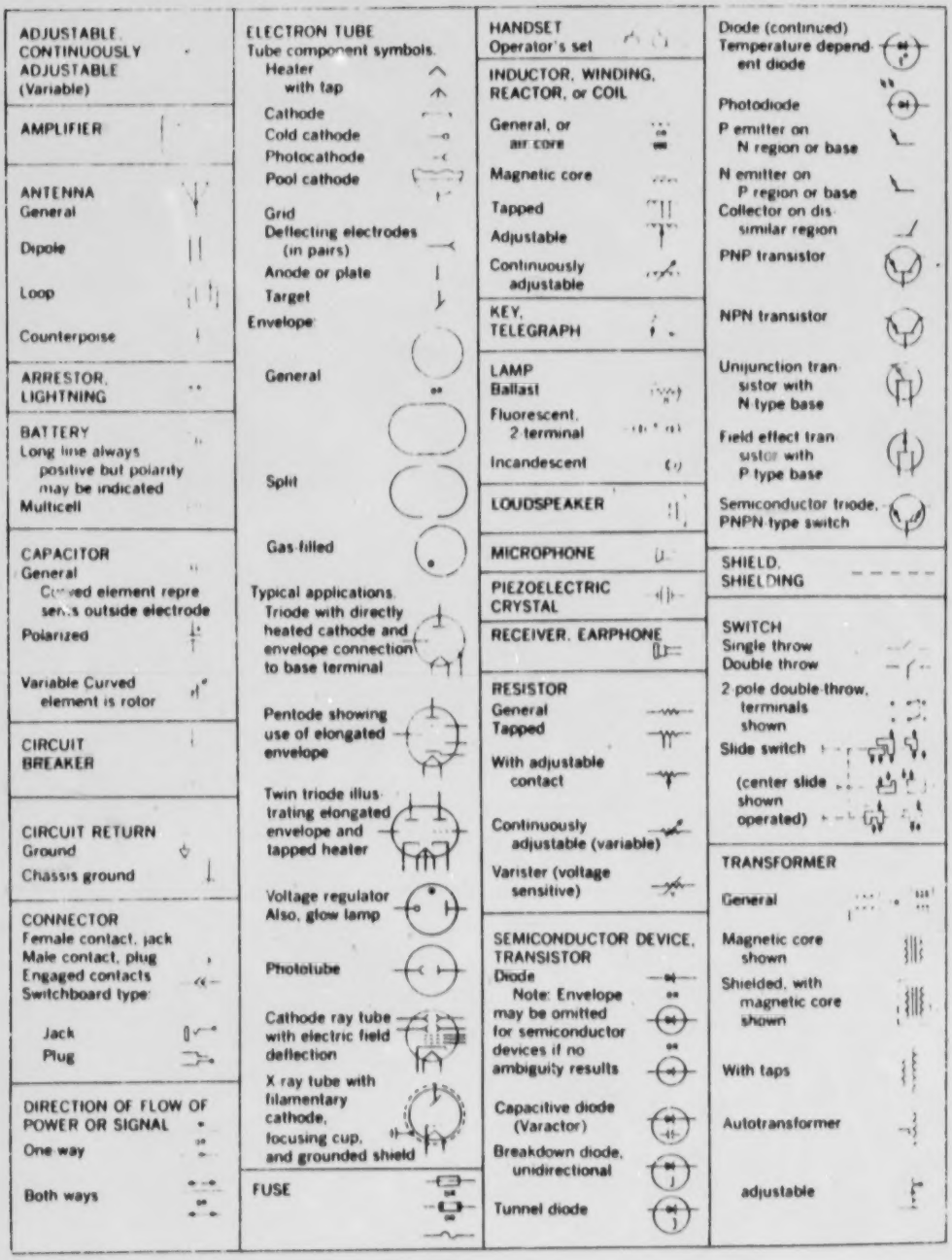


Figure 2-1 American Standard Graphical Symbols for Electronic Diagrams

	Type of Fitting	Single Line Convention	
		FLANGED	SCREWED
1	Joint		
2	Joint - Expansion		
3	Union		
4	Sleeve		
5	Reducer		
6	Reducer - Eccentric		
7	Reducing Flange		
8	Bushing		
9	Elbow - 45°		
10	Elbow - 90°		
11	Elbow - Long radius		
12	Elbow - (turned up)		
13	Elbow - (turned down)		
14	Elbow - Side outlet (outlet up)		
15	Elbow - Side outlet (outlet down)		
16	Elbow - Base		
17	Elbow - Double branch		
18	Elbow - Reducing		
19	Lateral		
20	Tee		
21	Tee - Single sweep		

	Type of Fitting	Single Line Convention	
		FLANGED	SCREWED
22	Tee - Double sweep		
23	Tee - (outlet up)		
24	Tee - (outlet down)		
25	Tee - Side outlet (outlet up)		
26	Tee - Side outlet (outlet down)		
27	Cross		
28	Valve - Globe		
29	Valve - Angle		
30	Valve - Motor operated globe		
31	Valve - Gate		
32	Valve - Angle gate		
33	Valve - Motor operated gate		
34	Valve - Check		
35	Valve - Angle check		
36	Valve - Safety		
37	Valve Angle safety		
38	Valve - Quick opening		
39	Valve Float operating		
40	Stop Cock		

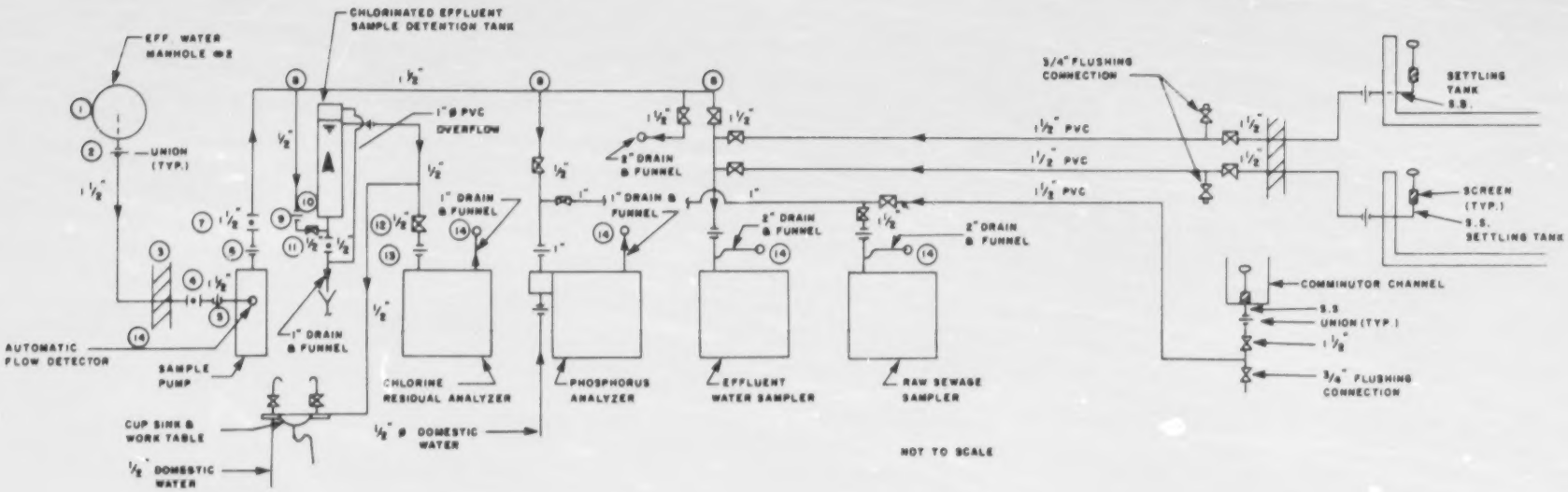
Figure 2-2 Piping Symbols

INTERPRETATION OF SCHEMATICS

This section considers the use of symbols in the schematic drawing. The symbols serve as a means of simplifying the graphic description of a component such as a valve or pump. The schematic drawings simplify the more complex mechanical/construction drawings of a project, as well as demonstrate the relationship of the components of the system. With this in mind several schematics may be drawn to clarify the major parts of a project. (Figure 2-3) which is taken from the flow diagram schematic of a small sewage treatment plant.

In the schematic, two items should be noted. Firstly it is not drawn to scale (N.T.S.) This emphasizes the purpose of the schematic - to show the links of the system, not how to construct it in detail. Secondly there are several legends placed directly on the drawings. These provide the definition of the symbols used, and eliminate possible misinterpretation through the use of an incorrect standard. Also provided in the legend are specifics on the item from material type to supplier. This particular schematic covered chlorination, water supply, chemical and sampling systems. For ease of reference during the following discussion of the sampling system, the components in the direction of sample flow are numbered.

Note that the sample pump is not identified by symbol but actually stated for what it is. One can see that the sample pump can be isolated by the ball valves (4) and (7) or removed through use of the unions (5) and (6).



LEGEND

SYMBOL	DESCRIPTION	MATERIAL	TYPE CLASS	TYPICAL MANUFACTURER	SERIAL NO, FIG ETC. MODEL NO
———	SAMPLING LINE FITTINGS	PVC PVC	SCHEDULE 80 SOCKET WELD HEAVY DUTY	——— ———	——— ———
—⊣o⊢—	BALL VALVE	PVC	TRUE UNION TYPE	CHEMLINE PLASTICS LTD.	CTU SERIES
	SAMPLING PUMP	———	PROGRESSING CAVITY 10 GPM	MOYNO.	———
—⋈—	SAMPLING LINE VALVE	CI NEOPRENE	DIAPHRAGM WEIRLESS TYPE	TRANE SAUNDERS	KB 31-2-T
—⋈—	FLUSHING CONNECTION HOSE VALVE	BRONZE	WITH CAP & CHAIN	JENKINS	FIG. 305 & FIG. 858
	INTAKE SCREEN	STAINLESS STEEL	SEE DETAIL M-10	———	———
	CHLORINE RESIDUAL ANALYZER	———	0.2 MG/LITRE	FISHER & PORTER	MODEL 1752 4-20 MG
	PHOSPHORUS ANALYZER	— —	DUAL RANGE 0-5 & 0-50 MG/L	DELTA SCIENTIFIC	SERIES 8042 4-20 MG
	EFFLUENT SAMPLER	———	FLOW PROPORTIONAL	SIRCO	SERIES B/ST-VS WITH FTC ADAPTOR
	RAW SEWAGE SAMPLER		FLOW PROPORTIONAL	SIRCO	SERIES B/ST-VS WITH FTC ADAPTOR
o	AUTOMATIC FLOW DETECTOR	C.I. RUBBER LINED	FLANGED	MOYNO	MOYNOR MONITOR

2-10

68

63

The varsatility of a system can be quickly detected and commented on it for change, if it is required and before it has become fact.

To further simplify the schematic the automatic flow detector (14) is not given a complicated symbol, simply an "O" and this is stated in the legend of the schematic. At this point, (8) the flow can be split into three different uses from the common 1½" line:

(a) chlorine residual analyzer
(b) phosphorus analyzer
(c) sample collection

the diameter of the piping is shown and there is a reduction to one half inch for each of the above functions.

Numbers 10 and 11 are both valves but two different types. The symbols show what they are and the legend gives specifics, 10 providing flow control, 11 used for straight discharge, not flow regulation. Items such as the detention tank are labelled on the drawing Number 12, the sampling line valve provides the ability to control the rate of flow.

One can readily establish that the rate of flow can be adjusted into each of three areas and it can be varied and measured as well.

Using the same schematics, one can identify the components in the lines from settling tank to chlorine and phosphorous analysers.

What has the schematic done? It has provided a built-in legend to identify the symbols used, and the specifics about each item which requires the additional information. It has provided a simplified but a complete representation of the arrangement of the components of one part of a large project. It therefore gives one the means to assess the capabilities of the system that the operator will be required to maintain.

PLAN READING

Before anyone can interpret plans and drawings correctly he first must have a knowledge of the elements of drawing. Drawing may be defined as the graphic language in which are expressed and recorded the ideas and information necessary for the building of machines and structures, as distinguished from drawing as a fine art.

Because drawing is actually a graphical language, it can only be understood by someone familiar with the language. It cannot be read aloud but must be interpreted by forming a mental picture of the subject concerned. When instruments are used, the language is that of mechanical drawing; when it is accomplished with the unaided hand, it is known as freehand drawing or technical sketching.

Drawing Principles

In drawing any object, full information is required regarding its shape and size; and the problem in engineering drawing is to reproduce the three dimensional shapes of the object, on the surface of a sheet of paper which has only two dimensions. Artists draw objects as they appear and not as they really are. This is "perspective drawing".

To meet the requirement of engineering drawing, the system of "orthographic projection" is used. Practically, this means that the drawing consists of a set of separate views of the object taken by the observer from different positions and arranged relative to each other in a definite way. Each of these views will show two of the three dimensions, and thus a combination of views will show all three dimensions.

To illustrate orthographic projection, the observer may imagine that the object is surrounded by a transparent glass box with hinged sides. The projections on these sides, made by extending perpendiculars from the object, are what would be seen by looking straight at the object from positions directly in front, above and from both sides, as well as from the bottom and rear. These sides of the box, or "planes", are then to be thought of as being opened up into one plane, the plane of the paper. The projection on the front plane is known as the front view or front elevation; that on the horizontal plane, the top view or plan; and that on the side or "profile" plane, the side view, and view or side elevation. Only rarely are the bottom and rear view required. The most usual combination of views is top, front and right side views. Sometimes the left side view is shown if it describes an object more clearly.

From the foregoing study the following principles will be noted:

1. The front view in a drawing indicates the width and height of an object but not the depth from front to back.
2. The top view is directly over the front view and gives the width and depth of the object.
3. The side views are in line horizontally either with the front or top view (usually the front view) and show the height and depth.
4. The depths of the side view are exactly the same as the depth of the top view.

To describe an object completely a drawing should contain lines representing all the edges, intersections and contours of the object. In any view there will be some parts of the object that cannot be seen from the position of the observer as they will be covered by portions of the object closer to the observer's eye. The edges, intersections and contours of these hidden parts, although actually invisible, have their location indicated by the symbol of a lightly drawn line made up of short dashes, commonly called a "dotted line". In drawing, when two lines coincide the nearer one has precedence and the full line always has precedence. In other words, the edges of an object actually visible in any particular view appear as full lines on the drawing, and edges, not visible, take the form of dotted lines, unless coinciding with full lines.

If the object is very simple in its interior construction the hidden lines are not hard to read and understand. Often however, when the interior is complicated or when several different pieces are assembled in one place, an attempt to show the construction on an exterior view would result in a confusing mass of dotted lines, annoying to draw and difficult to read clearly. In such cases one or more of the views is made "in section". A sectional view or section is a representation in which a part of the object is imagined to be cut away and removed so as to expose the interior. The cutting plane is always indicated on the particular view of the drawing to which the sectional view is related. This cutting plane need not be a continuous single plane but may be changed in direction so as to show the construction to best advantage. Material which has been cut by the section plane is indicated by fine diagonal lines called "cross-hatching", uniformly spaced across the cut surface. Invisible lines beyond the plane of the section should not be drawn unless necessary for a clear description.

In representing objects that are larger than can be drawn to their natural or full size, it is necessary to reduce the size of the drawing in some regular proportion. Every such drawing has this proportion or scale marked on it, which indicates the number of inches on the drawing that would be equivalent to an actual measurement in feet. Drawings of objects have scales of usually 1/3, 1/4 or 1/2 inch equals one foot; whereas scales for maps are often one inch equal to 200 or 300 feet. The scales should always be clearly indicated on drawings.

After the shape of the object has been described the value of the drawing for construction purposes depends upon the dimensioning and notes to tell the size. Complete dimensions are made up of dimension lines, arrowheads, extension lines, leaders, figures and notes. In all cases, sufficient size and location dimensions should be marked so that the essential elements are properly defined.

Reading a Drawing

A drawing is read or interpreted by forming a mental picture of the object represented. In forming this mental picture, one must first gain a general idea of the shape of the object by a rapid survey of all the views given, then select for more careful study the view that best shows the characteristic shape, and by referring back and forth to the adjacent views see what each line represents.

In looking at any view one should always imagine that it is the object itself, not a flat projection of it, that is seen, and in glancing from one view to another the reader should imagine himself as moving around the actual object and looking at it from the direction the view was taken.

The actual size of the object or structure or any part thereof, may be observed by reading the dimensions or by measurement of the drawing itself, using the particular scale involved.

There are two types of drawings that can be most beneficial to the plant operator, the construction drawings and the mechanical drawings.

Construction Drawings

Its purpose is to present the information that is required to build the structure which will hold the equipment needed. The contractor will use these drawings to establish elevations from the footings to the roof tops. These drawings include the detail regarding where to place the reinforcing rods, the type of concrete to use and the size of steel. The larger plants will require many construction drawings in order to show all the detail required. By means of sectioning one view into several sub-sections, a complex plan can be simplified. In this way the measurements can be more detailed allowing for more accurate installation of equipment.

Mechanical Drawing

Mechanical drawings illustrate the location of non-structural items such as pumps and piping. This drawing will also include the location of future design items, usually shown by a broken line drawing.

By making use of these drawings, one can observe the structural requirements, the location of the equipment and future design considerations. Finally, an overall view is given showing the relationship of the parts of the system, one to the other so that it is possible to form a mental picture of the complete project.

Study a drawing systematically section by section - structural to mechanical to schematic flow diagrams as required. Generally no one drawing will show all the information.

INSTRUCTIONS No.5400B-H

FOR INSTALLING AND OPERATING
FAIRBANKS MORSE
HORIZONTAL NON-CLOG PUMPS
SERIES 5420B, 5450B

SECTION 1
INTRODUCTION

The pumps covered by these instructions, when properly installed and when given reasonable care and maintenance, will operate satisfactorily for a long time. To insure the proper installation and maintenance, these instructions should be read carefully.

DESCRIPTION

The pumps covered by this manual are all basically the same in respect to the hydraulic end; however, the frames and drivers are divided into two basic types as follows:

1. Horizontal Frame Pumps

This type of pump is equipped with ball bearings and is designed to operate in a horizontal position. The driver is generally mounted with the pump on a common base. The pump and driver are usually connected with a flexible coupling.

2. Horizontal Biltogether Pumps

This type of pump is not equipped with bearings as the hydraulic parts are mounted directly on the motor. This pump is also designed to operate in a horizontal position.

GENERAL APPLICATION

These pumps are basically designed for handling liquids containing solids or stringy materials and are, therefore, termed non-clog pumps. They are furnished standard with a two-passage impeller which will perform satisfactorily for most applications. However, in applications where extremely stringy material is being handled, these pumps may be equipped with a single passage impeller which is termed "bladeless design." These pumps are recommended for handling raw or treated sewage, light sludge, slurries, industrial material or wastes, and similar liquids where excessive clogging would otherwise be encountered.

CHECKING FOR TRANSIT DAMAGE

Upon receipt of this pump, a visual check should be given to determine if any damage has been incurred in transit or handling. The main things to look for are:

1. Broken or cracked feet on the base.
2. Broken or cracked suction or discharge flanges.
3. Broken or cracked adapter (See Piece No. 426 in the illustrations).
4. On the motor, check for broken end bells, bent eye bolts, broken or cracked feet, and damage to the conduit box.

If any damage has been incurred, PROMPTLY notify your nearest Fairbanks Morse Pump Division representative AND the transit company that delivered the pump.

PRESERVATION

In the event that this pump will not be installed immediately, steps should be taken to protect the pump from moisture damage, dust, dirt, and pests. It is recommended that the following steps be taken:

1. Fill the bearing housings completely with suitable grease. (See Section 4, Lubrication topic.)
2. Remove the glands, packing and seal cage from the stuffing box if the pump is equipped in this manner. If the pump is equipped with a mechanical seal, remove the pipe plug in the seal housing and coat the seal with a heavy oil or grease. This may be done by using an oil can, squirting on the sealing surface while rotating the pump shaft.
3. Cover the pump suction and discharge flanges with cardboard, wood, or masking tape to prevent foreign objects and pests from lodging in the pump.
4. If the pump is to be stored where there is no protective covering, it is advisable to cover the pump with a tarpaulin or other suitable means.

SECTION 2
INSTALLATION

PREPARATION

Before installing the pump, the suction and discharge flanged surfaces must be cleaned, and, using a solvent, remove the protective coating from the pump shaft.

If the pump has been in storage, and prepared for storage in the manner outlined in Section 1, it will be necessary to remove all of the grease from the bearings. The bearings should then be flushed with a suitable compound, and regreased. The proper procedure for performing this operation is outlined in Section 4

LOCATION

The pump should be located as near to the liquid being handled as practical so that a short, direct suction pipe may be used. The total suction lift should not exceed 15', or the required NPSH stipulated, when pumping rated capacity at sea level and the temperature not exceeding 85° F. The correction for altitude is approximately 1' suction lift for each 1000' above sea level. Also, for ease of maintenance and inspection during operation, it is advisable to locate the pump so that it will be readily accessible.

DESCRIPTION

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively, as shown in Fig. 1. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a "two-stroke cycle".

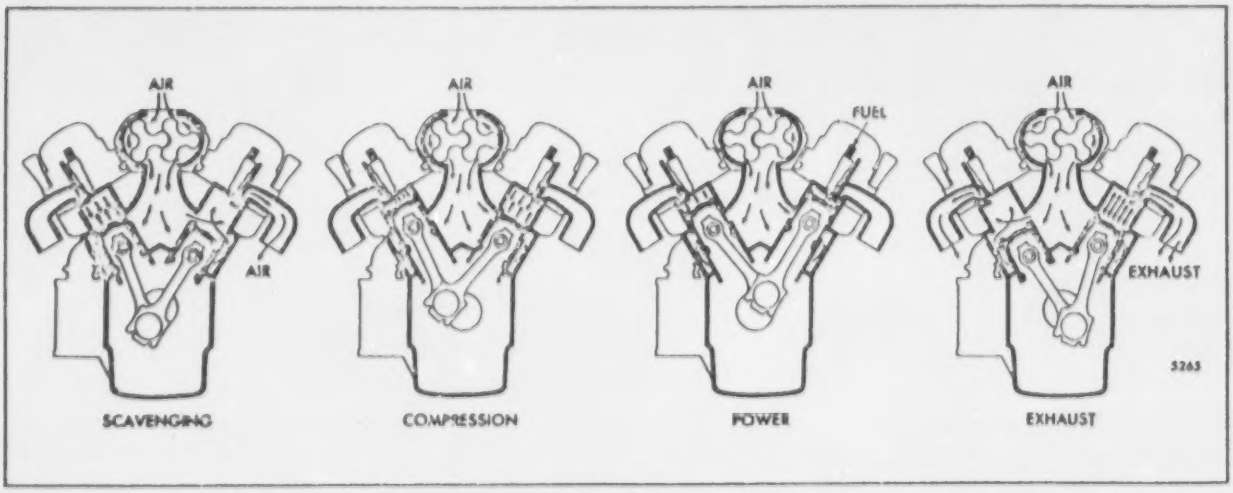


Fig. 1 - The Two-Stroke Cycle

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily upon:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed, and hard starting may be caused by either low compression, faulty fuel injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve rocker cover(s). Discard the gasket(s).

3. Check the valve clearance. The clearance should be .009" (two valve cylinder head) or .014" (four valve cylinder head).

4. Start the engine and hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. Provided that the injector operating mechanism of the faulty cylinder is functioning satisfactorily, remove the fuel injector and install a new one by performing the removal and installation procedure outlined under *Fuel System*.

7. If installation of a new injector does not eliminate misfiring, check the compression pressure.

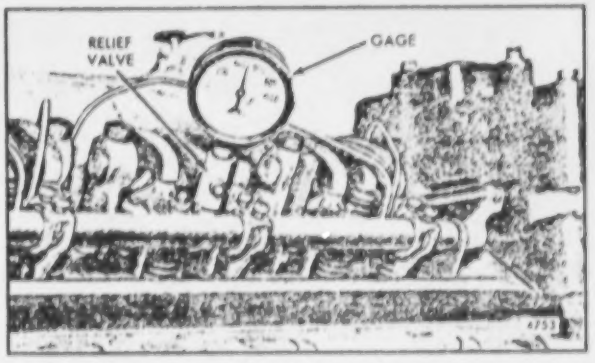


Fig. 1 - Checking Compression Pressure

Checking Compression Pressure

Compression pressure is affected by altitude as shown in the following table.

Minimum Compression Pressure, psi		Altitude, Feet Above Sea Level
Standard and Turbocharged Engines	"N" Engine	
425	515	0
395	480	2,500
365	440	5,000
340	410	7,500
315	380	10,000

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

2. Stop the engine and remove the fuel pipes from the No. 1 injector and the fuel connectors.

3. Remove the injector and install adaptor J 7915-02 and pressure gage and hose assembly J 6992 (Fig. 1).

4. Use a spare fuel pipe and fabricate a jumper connection between the fuel inlet and return fuel connectors to permit fuel to flow directly to the fuel return manifold.

5. Start the engine and run it at 600 rpm. Observe and record the compression pressure indicated on the gage.

> **NOTE:** Do not crank the engine with the starting motor to check the compression pressure.

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder should not

SUBJECT:

PREVENTIVE MAINTENANCE

TOPIC: 3

MAINTENANCE OF PIPING AND VALVES

OBJECTIVES:

The trainee will be able to:

1. Recall the basic principles of a scheduled routine maintenance system.

2. Recall the basics of a maintenance record system.

3. Recall methods of identification of piping.

4. Recall scheduling of pipeline maintenance.

5. Recall the following methods of pipeline cleaning:

   (a) mechanical
   (b) hydraulic
   (c) thermal
   (d) chemical

6. Recall the procedures involved in the cleaning of sludge and scum pipelines.

7. Recall the use and characteristics of valves.

8. Recall the maintenance procedures of valves.

9. Recall the safety factors on pipeline maintenance.

Scheduled Routine Maintenance System

A satisfactory scheduled routine maintenance system should result in a reduction in the number of breakdowns (unscheduled shutdowns), and in lower overtime charges. At the same time it would, hopefully, improve the overall efficiency of the plant and simplify the task of continuously producing a high quality effluent.

The mechanics of how to set up a scheduled preventive maintenance program are not complicated, even though, for large plants the process may be involved and time consuming. The manufacturers instruction manual will provide a recommended schedule of maintenance which may have to be adjusted to suit unusual conditions of service and environment. Setting up the program is the easiest part; the difficulty lies in the implementation and continuance of the schedule, for this is where the dull, uninteresting office routine can wreck the program. It would seem then, that the success or failure of a scheduled routine maintenance program depends more on the integrity of administrative personnel than it does on personnel who actually perform the maintenance. A close look at the ineffectiveness of a well planned record system will confirm this hypothesis.

It is not enough to establish a procedural system of any kind and then divorce oneself from the operation of the system. To do so will almost certainly lead to the eventual decay and abandonment of a very costly enterprise and every cent spent will have been wasted. Even worse, the morale of all concerned will suffer a reverse that may lead to a "what the heck" attitude. Before embarking on a scheduled routine maintenance program one must understand that it will require even more effort and dedication to operate the program than it will to set up the program. Therefore, if one is not prepared to or does not have the means to put out this continuous effort, then, one should not waste resources on a halfhearted effort.

Some guidelines on the design and set up of a Scheduled Routine Maintenance Program are as follows:

1. Research and review maintenance requirements. Is a program really needed?
2. Establish attainable objectives. Do not aim too high, concentrate on essentials.
3. Involve operating and maintenance personnel in the design and development of the system as much as possible.
4. Introduce the system as a pilot for test purposes.
5. Do not complicate the system; design for simplicity and utility.
6. Prepare a Users Manual and keep it up-to-date.
7. Train personnel in the operation of the system.
8. Keep design and operating costs to a minimum.
9. Do not move too quickly; prove each step before proceeding with the next.

Some of the variables that must be taken into consideration when establishing a maintenance schedule are as follows:

1. Peak and off-peak production periods - availability of equipment for maintenance.
2. Climatic conditions - the seasons of the year.
3. Availability of competent manpower - vacations, etc.
4. Conditions of warranty on new equipment.
5. The effectiveness of the existing maintenance program.
6. Availability of funds.
7. The attitude of top management towards scheduled preventive maintenance.

Some of the objectives of a scheduled maintenance program are as follows:

1. To reduce the incidence of unscheduled maintenance (breakdowns).
2. To provide a balanced workload.
3. To improve the reliability of equipment and maintain a treatment process of consistantly high quality.
4. To project maintenance activities for the future so that spare parts, materials and manpower can be on hand when needed.
5. To accumulate a history of maintenance that can be used to evaluate the equipment at time of replacement, also, to evaluate and review maintenance activities and procedures.

In advancing the case for a Preventive Maintenance Program, no claim of lower maintenance costs has been made; lower overtime charges, yes, but not lower overall maintenance costs. When carrying out preventive maintenance activities the greatest portion of the work done is investigative, i.e. inspections. This type of work is not carried out under a breakdown maintenance regime. Therefore the cost of the investigative work load plus the operating costs of the program should be included in any monetary evaluation of a scheduled Preventive Maintenance Program. There are sufficient grounds for justifying the adoption of a preventive maintenance program without making extravagent claims of lower costs. Lower maintenance costs cannot be realised by preventive maintenance programs, and hopes to the contrary will lead to disappointment.

Maintenance Record System

The definition of the noun "Record" (Funk & Wagnalls) is:

1. "An account in written or other permanent form serving as a memorial or authentic evidence of a fact or event".
2. "Something on which an account is made, as a document or monument".
3. "Information preserved and handed down, etc."

Therefore a maintenance record must be written, permanent, authentic, factual and must be preserved until needed at some future time. A note written on a piece of paper does not constitute a record unless it can be preserved and recovered whenever it is needed. It is possible to store information in just about anything from a Note Book, Daily Journal, File Card up to a Computer Memory bank. The means by which information is stored is not as important as the facility with which the information can be recovered whenever it is needed.

A well designed record system can be a valuable tool for the operator to have at his disposal, but only if he is prepared to provide the input of information. The best system available will not be capable of giving out more information than it received. Record systems should never be considered to be complete but should be under constant review and evaluation. The system should possess sufficient flexibility to incorporate any changes deemed necessary by either re-evaluation and/or plant expansion.

Invest considerable effort into the planning phase of the record system; seek advice from all available sources; inspect other systems whenever you can. It is both wasteful and embarrassing to have to design a new system every few years. Companies that supply record keeping equipment will

be more than happy to give advice without obligation. They will also provide names and addresses of users so that you can inspect an established record system and question the personnel responsible for its operation. Finally, as many members of the organization as possible should be involved at the planning stage so as to give them a stake in the success or failure of the system.

It is not possible to go into detail on how to set up a record system. Systems must be tailored to suit a particular set of requirements and conditions. However, the following general observations should be of some value:

1. Design the system on a broad base but keep it as uncomplicated as requirements will allow.
2. The system must possess the capability of expansion to meet anticipated future requirements.
3. The system should not add to, but should reduce the overall workload of the supervisors.
4. Do not build a paper factory, include essential information only.
5. Provide the necessary training so that personnel can operate the system.
6. Constantly review and evaluate the system and, whenever necessary, make changes.
7. Prepare and keep up to date an instruction manual for the guidance of personnel who will be required to operate the system.
8. Maintenance activities should be scheduled so that the record system is in regular use. This will ensure that personnel will preserve their ability to operate the system effectively.

IDENTIFICATION/MAINTENANCE OF PIPELINES

Identification

It is essential that, when a number of pipelines conveying various fluids (liquids, gases and/or slurries) are stacked together or are passed through wall openings into other rooms or passage-ways that some means of identification be applied to each pipeline. There are several pipeline identification systems available, including the following:

1. Colour Code
2. Descriptive Identification
3. A Combination of 1 and 2

Special markings may also be required to warn operators of the direction of flow, dangerous fluids within the pipe, and dangerous conditions outside of the pipe. Each application must be considered in detail before acceptable procedures and rules can be adopted. The procedures and rules should be reviewed and evaluated on a continuing basis to take advantage of new techniques and equipment, and, in addition, to comply with changes to government regulations.

Colour Coding (See Fig. 3-1)

During the initial stages of treatment plant development, some design engineers and plant operators have displayed a marked preference towards Colour Coding. Unfortunately, the disadvantages of a colour code far outweigh the advantages. Some of the disadvantages of colour coding are as follows:

1. The number of contrasting basic colours is limited and will be found to be inadequate as additional processes are introduced to comply with governmental minimum quality standards.

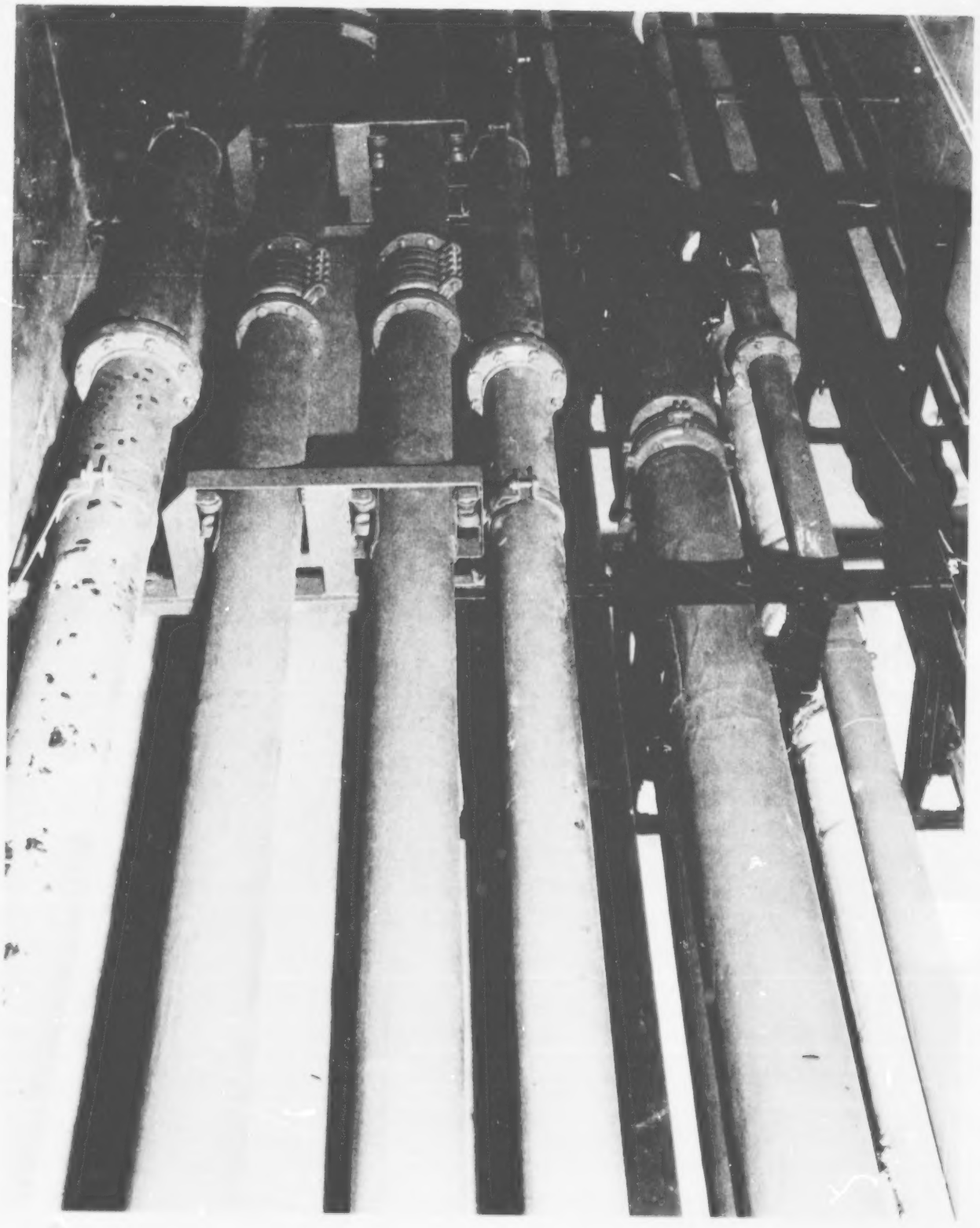


Figure 3-1 Colour Code - Pipe Stack

2. Operators afflicted by colour blindness are put to a great disadvantage when identification is by colour code only.
3. Identification by colour necessitates the use of a code or cipher. (Table 3-1). This is an additional complication that can lead to mistaken identification and possibly to accidents that result in damage to property and/or injury to personnel.
4. Both the original cost and maintenance costs are higher for a multicoloured pipe network than for a one colour network. The inventory of paints required to maintain the multi-colour system can be enormous, complicating paint touch-up work after maintenance.

Descriptive Identification (See Figure 3-2)

This method of identification is normally applied to a one colour pipe network and, although less pleasing to the eye than multi-colour network, it does have certain advantages when compared to colour coding. They are:

1. Lower original cost
2. Lower maintenance costs
3. Lower paint inventory costs (for touch-up)

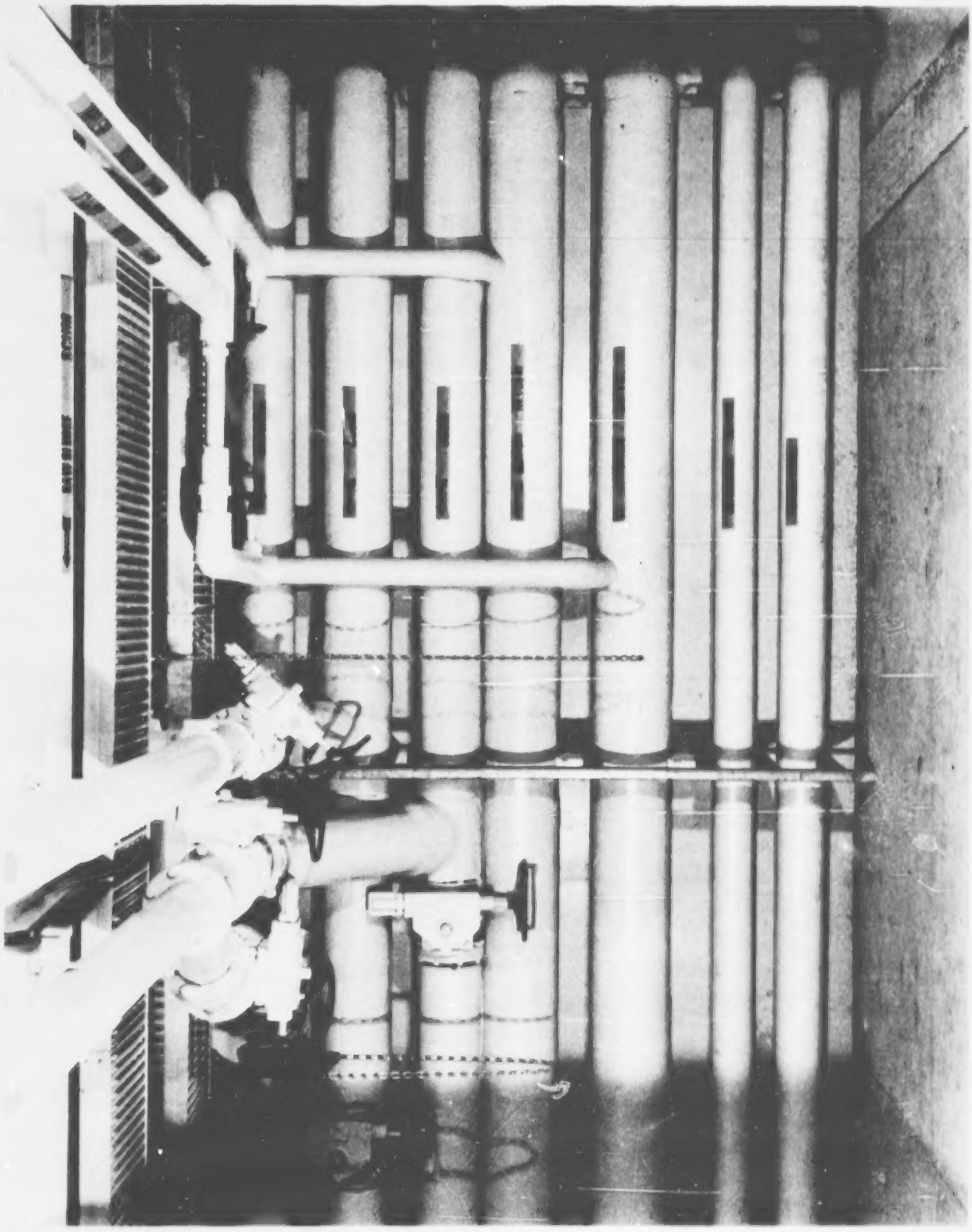


Figure 3-2 Descriptive Identification - Pipe Stack

TABLE 3-1 COLOUR CODE USED AT TREATMENT PLANTS & TYPES OF PAINT

PIPE LINES	COLOUR	INERTOL	VALDURA
Raw Sewage	Grey	307	302
Effluent	Grey	307	302
Raw Sludge	Grey	307	302
Drains (Plumbing)	Grey	307	302
Waste Mixed Liquor	Grey	307	302
Waste Activated Sludge	Grey	307	302
Primary Sludge	Grey	307	302
Tank Drainage Lines	Grey	307	302
Sump Pump Discharge	Grey	307	302
Digested Sludge	Black	321	314
Activated Sludge	Black	321	314
Elutriated Sludge	Black	321	314
Sludge Sampling Lines	Black	321	314
Sludge Sampling Lines or	Grey	307	302
Supernatant	Concrete Grey	309	2062
Circulated Sludge	French Grey	332	Tint to match
Transfer Sludge	French Grey	332	Tint to match
Raw Water	Dark Green	323	308
Flushing Water	Dark Green	323	308
Separated Water	Dark Green	323	308
Make-up Water	Dark Green	323	308
Compressed Air (including aeration and instrumentation system)	Light Brown	334	303
Potable or City Water	Blue	301	335
Special Coolant	Royal Blue	303	317
Hot Water	Light Green	336	813
Hot Water Engine Oil Cooling	Light Green	336	813
Heating System Piping	Wall Colour	-	-
Electrical Conduits	Wall Colour	-	-
Sludge or Digester Gas	Red	314	310
Natural Gas	Red (with one band of Buff)	314	310
Lime Slurry	Ivory	321	315
Fuel Oil	Maroon	316	307
Exhaust Piping	Maroon	316	307
Flue from Boilers	Maroon	316	307
Chlorine (liquid)	Yellow (Hansa Type)	319	6309
Chlorine (gas)	Yellow (Hansa Type)	319	6309
Chlorine (Solution)	Yellow (Hansa Type)	319	6309
Ferric Chloride	Light Orange	324	313
Filtrate	Dark Orange	Tint to match	328
Diesel Oil	White	311	318
Lube or Dirty Oil	Tan	325	334
Clean Oil	Buff	313	241
Combustion Air to Engine	Buff	313	241
Vacuum Piping	Buff	313	241
Steam	Aluminum	320	90
Condensate Return	Aluminum	320	90
Vents (relief on boilers)	Aluminum	320	90
Engine Crankcase Breather	Dark Brown	318	329
Cold Water Piping	Sea Green	304	6511
Engine Jacket Water	Misty Green	342	321
Vents (oil storage tanks)	Dawn Blue	328	335

4. Eliminates the need for a code or cipher
5. Makes life easier for the colourblind operator
6. Ensures that piping, removed for maintenance, is returned to the pipeline the correct way. This is very important whenever direction of flow indicators (arrows) are employed.

There are two common methods of applying the description. They are by adhesive labels or by stencilling. Of the two, stencilling is possibly the cheapest, and the means to identify equipment is always at hand once the stencilling set is purchased. On the other hand, applying adhesive labels is perhaps less time consuming and is made more attractive by the use of coloured labels. However, it may not always be possible to anticipate future requirements and this may lead to delays in the supply of labels unless a varied stock of labels is maintained at all times. Care must be taken to ensure that whenever pipe covering is removed for maintenance purposes it is either reinstalled or if replaced it is relabelled.

Combination Colour Coding/Description Identification

As the title implies, this system of pipeline identification employs both colour coding and description. It is sometimes used as a transitional stage from the colour code system to the descriptive system whenever the size and complexity of the plant processes has outgrown the availability of standard contrasting colours, or when the cost of maintaining a complex colour code is prohibitive. Governmental regulations applied to the identification of pipelines conveying dangerous fluids may prevent a complete change-over to descriptive identification by requiring a colour code. Nevertheless, it is recommended that in such special cases a combination of the required colour code and the description be applied.

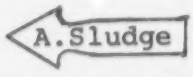
Direction of Flow

Flow indicators must be applied to the pipeline at regular intervals on straight pipe runs, whenever the pipeline passes through wall, floor and ceiling openings, and whenever the flow may be confusing to the operator by complicated valving and interconnections. Direction of flow indicators must be provided with a means of determining which is the upper side of the arrow, thus:

Wrong

Right

Right



Right

The ability to orient the directional arrow is essential to prevent a length of pipe or pipe fitting, removed for maintenance, being inverted when returned to the pipeline and indicating a false direction of flow.

Dangerous Fluids

Steam, hot water, acidic and/or caustic solutions, as well as toxic and/or explosive gases, should be identified either by colour code, description, or a combination of the two. Be generous with the markings, markings should be visible along the pipe run from any position. Valves on pipelines transmitting dangerous substances should also be provided with the capability of being locked in the closed position.

In addition to printed warnings of dangerous contents, we must provide some protective warnings for the sensitive interiors of some pipelines. Pipelines manufactured from non-metallic materials are replacing iron

and steel pipe in many treatment processes, and even when metallic pipe is in use it may be lined with either glass, rubber or plastic. Therefore, extreme care must be taken to identify a pipeline that requires special cleaning procedures and tools, otherwise the pipe or lining may be damaged, resulting in expensive repairs or replacement.

Magnetic flow meters employ an insulated tube that is easily damaged by the passage of metal rods and/or augers. A printed warning must be posted on the pipeline at each point of access, together with the approved method of cleaning the pipeline.

Dangerous Conditions Outside the Pipe

Warnings should be posted along the pipeline for the protection of personnel against hidden hazards, i.e. electrical, steam and/or hot water tracing buried within or covered by the insulated covering (lagging) of the pipeline. In the case of electrical tracing it may be necessary to provide an electrical disconnect switch with provision for locking out to conform to safety regulations.

Maintenance

Pipelines are, possibly, the most neglected equipment employed in both water and sewage treatment processes, yet they are of prime importance. Rarely are they included in preventive maintenance programs but they are ignored until they break or become plugged. In both cases, water and sewage, the end result is the same, interruption of plant processes for unscheduled maintenance. A relatively small leak from a water main will, if neglected, increase to

proportions that may undermine the pavement and/or adjacent pipelines or sewers, and, in addition it may reduce the system head sufficient to cause the overloading of motors on centrifugal pumps. Loss of pressure in the pipeline can result in the infiltration of polluted ground water into the system. Plugged or restricted sludge and/or scum pipelines, on the other hand, will result in an increased system head that can cause the overloading of positive displacement pump motors, failure of shear pins or the operation of other protective devices.

Scheduling of Maintenance

The following procedures carried out routinely can be effective as a means of determining the internal condition of a pipeline without the need for an internal inspection.

1. Observe and record changes in the system head at pressure gauges down stream of the pump.
2. Observe and record changes in flow rates indicated by metering devices.
3. Observe and record changes in motor loading indicated by the ammeter.

The effectiveness of these methods can be improved by the installation of indicator flags to gauges and meters indicating the normal current, pressure, and flow rate.

The chronological scheduling of sludge and scum pipeline maintenance has little to recommend it. Rarely do pipelines plug to a time table. Whenever the incidence of plugging reaches unacceptable levels the pipeline should be cleaned out back to the sump or hopper supplying the pipeline.

Pipeline maintenance should of course include the pipe exterior elements, such as:

1. Repair and painting of pipe insulation
2. Secure, repair, replace, adjust and paint pipe hangers, brackets, clamps, etc.
3. Tighten flanges and replace gaskets
4. Maintenance of pipeline identification markings

External maintenance of pipelines can be scheduled by hours of operation or elapsed time.

Due to the composition of the material handled, certain pipelines are subject to plugging. Included are:

1. Drains from sedimentation and settling basins in Water Purification Plants.
2. Sludge and scum pipelines in Sewage Treatment Plants.
3. Ash slurry pipelines from incineration process in both Sewage Treatment and Solid Waste Disposal plants.
4. Floor drains whenever the protective gratings are removed.

Preventive action plays an important role in the struggle to prevent plugged pipelines. The following are a few examples:

1. Remove all restrictions from the pipeline, i.e. plug valves with rectangular or diamond shaped ports, diaphragm valves, globe valves, valves of less than full pipe size.

2. Flow meters employing either a Venturi tube or an orifice plate are not recommended for use on sludge or scum pipelines.
3. Magnetic flow meters are recommended for such duty, provided precautions are taken to avoid damage to the insulated tube by the display of warning notices.
4. Long radius elbows and sweep fitting on tees and on cross branches are recommended whenever rods and augers, etc. are used for pipeline cleaning purposes.
5. The plugging of scum pipelines is usually the result of scum being left in the pipeline and allowed to harden. Flushing the pipeline with hot water after each scum pumping session will prevent this type of plugging.
6. In addition to 5 above, scum pipelines should be adequately insulated with lagging to retard heat loss.
7. Tracing scum pipelines by means of steam, hot water or an electric element is another effective preventive measure. In addition, tracing can be effectively employed in the clearing of blocked scum pipelines. Pipe is obtainable with the steam and/or hot water tracing line integral with the main conduit. However, a more commonly used method is to attach the tracing to the outside wall of the scum pipeline and then encase both in an insulated covering.
8. The emergency tracing of scum pipelines by passing a steam or hot water tracing through the interior of the scum pipeline has been adopted in the past. It is, however, a desparation measure, necessitated by the

scum line being buried and therefore inaccessible to the operator. This method is not recommended, it has too many disadvantages, such as:

(a) Creating an increase in the system head
(b) Requires troublesome glands where the tracing enters and leaves the scum pipeline
(c) Prevents rodding operations unless removed
(d) It may, in itself, be the cause of mechanical plugging

Characteristics of Steel/Wrought Iron Pipe

Attached for information as Appendix A are notes on the characteristics of steel and wrought iron pipe.

Methods of Pipe Manufacture

Attached for information as Appendix B are notes on the methods of pipe manufacture.

Pipeline Cleaning

There are at least four methods of cleaning pipelines:

1. Mechanical (rods, hammers, augers and cutters, etc.)
2. Hydraulic (high pressure hoses, high velocity nozzles)
3. Thermal (steam, hot water and electric element)
4. Chemical (acids or caustic solutions)

Mechanical Cleaning

Pipeline cleaning equipment is available in such a wide variety and from so many reputable suppliers that it would not be fair to discuss any particular type or manufacturer in detail. With minor differences they are all very much alike at first glance, it is only after using equipment for some time that a true evaluation can be made. As much information as possible should be obtained before ordering equipment. A reputable supplier will gladly provide the names and phone numbers of their customers, from whom information can be obtained.

Hydraulic Cleaning

Hydraulic cleaning can mean everything from a flushing procedure to high pressure cleaning with high velocity nozzles. High pressure hoses can be used with turbine driven cutters and hammers to remove hard scale and deposits as for instance are found in boiler tubes, etc. High velocity nozzles are effective in removing semi-hard, clay or sandy deposits by the cutting action of the high velocity jets of water. Hydraulic cleaning can of course be allied to mechanical cleaning to flush out the loosened solids.

Thermal Cleaning

Thermal cleaning is usually applied to grease and scum build up in pipelines, it can be effectively used as a preventive measure as with tracing. Portable steam generators are extremely useful for the direct removal of grease. They are preferable to fixed boiler installations where the boiler feed water is treated and the unrestricted use of make-up water is to be discouraged. In addition, a fixed boiler system may require a prodigious amount of piping to cover the entire plant.

Chemical Cleaning

Both acidic and caustic solutions are involved in the chemical cleaning of pipelines, however, it may be somewhat dangerous to generalize on the subject of chemical cleaning. The use of chemicals should not be undertaken unless professional opinion is obtained and followed, at least initially and whenever a change of chemical or procedure is anticipated. Extreme care must be taken and protective clothing and equipment worn whenever chemicals of this nature are being used.

A job is never completed until the tools have been returned to their proper place, and the job site has been cleaned up and is restored to an acceptable level of cleanliness.

PIPELINE CLEANING (SLUDGE & SCUM)

Preventive measures notwithstanding, pipelines will, for various reasons, become restricted or plugged. It is essential that timely and adequate preparations be made to effectively deal with the problem when it does occur. Preparations should include the following:

1. Divide the pipeline into sections of approximately 150 feet, or in lengths within the range of the cleaning equipment.

2. Install a means of access at each end of each section of pipeline. Whenever the direction of the pipeline is changed at an access point install either a tee or a cross branch. When a section terminates in a straight run of pipe install a short makeup piece.

3. To speed-up the opening and closing process of the pipeline it is recommended that quick operating pipe connections be employed, similar to either Victaulic 2-bolt or Victaulic snap-joint couplings.

The practice of using 3 or 4 bolts to secure flanges drilled for a 6 or 8 bolt fastening should be discouraged. Not only is it unsightly and hard on flange gaskets, it is also a dangerous habit that could be carried over to high pressure applications.

4. Flanges and pipe fittings at access points should not, for obvious reasons, be covered with insulated pipe covering.

5. Pipe hangers are not suitable for supporting pipelines that will require cleaning by rods, augers, etc. The pipeline should be rigidly clamped to wall brackets at a height of approximately 3 to 4 feet, so that effective rodding operations can be carried out (Fig. 3-1).

6. Whenever pipelines are to be stacked in two or more vertical rows, pipelines that will require cleaning should be located to the inside of the stack, that is, nearest to the operator.

7. It is recommended that each access point be provided with adequate lighting, a power outlet, a supply of flushing water and adequate drainage. In addition, it is recommended that the floor at each access point be coated with a non-slip paint.

8. Whenever a pipeline is manufactured of material other than iron or the pipeline is lined with rubber, plastic, glass or any substance not compatible with the established cleaning methods, a warning notice must be posted at each access point.

9. Personnel must also be warned not to pass steel cleaning rods and/or augers, etc. through the tube of a magnetic flow meter, otherwise the tube will sustain damage that will be costly to repair.

USE AND CHARACTERISTICS OF VALVES

Line valves are the means by which flow through a pipeline is either started, regulated or stopped. It is essential, therefore, that operators and maintenance personnel be sufficiently knowledgeable to be able to select the correct valve for a given application, then install and maintain it so that it will perform satisfactorily.

Gate Valves

There are two types of gate valves, one with a rising spindle (Figure 3-3) and one with a non-rising spindle (Figure 3-4) used for fully open/fully closed (starting/stopping) flow operations. Some important characteristics are:-

1. Tapered gate and seat will cause turbulence and vibrations when only slightly opened. Unless the gate is returned to the seat, damage to both faces can result. Under high head/flow conditions slight unseating such as this will result in "wire drawing" and erosion of both seat faces.

2. High head conditions being applied to one side of the gate could make opening extremely difficult if not impossible. Flooding the dewatered side of the gate to equalize the pressure by means of a by-pass will not only simplify the opening process but will also prevent damage to the seats and/or the spindle.

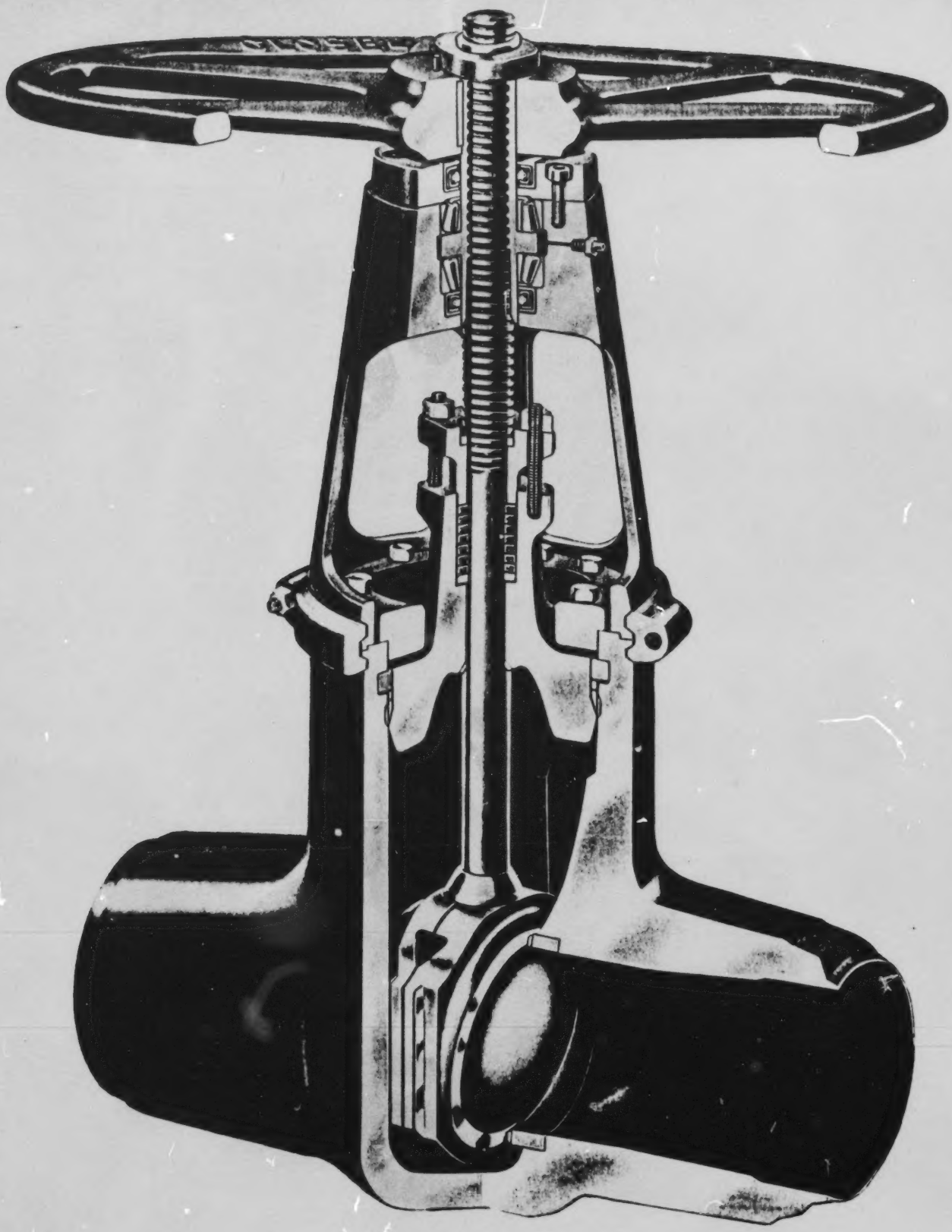


Figure 3-3 Gate Valve - Rising Stem

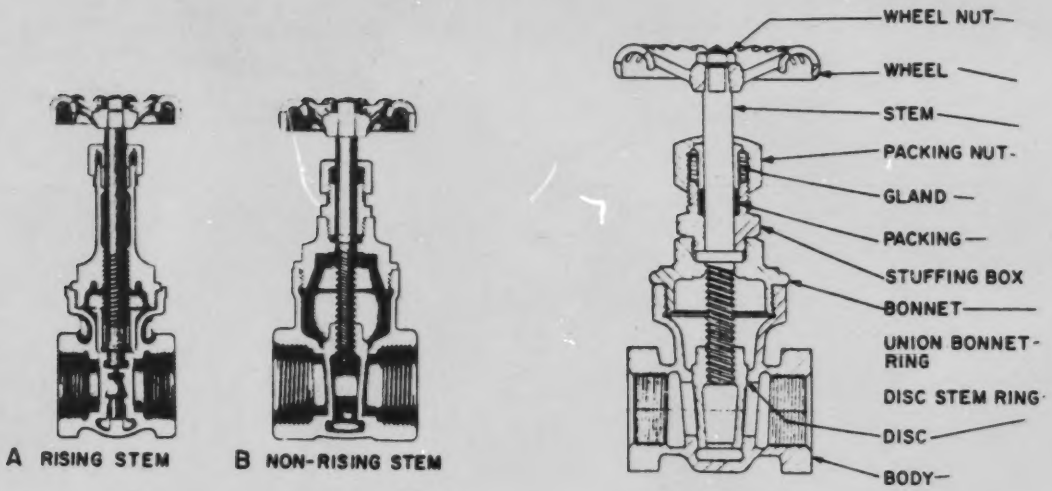


Figure 3-4 Gate Valve - comparison of Rising Stem and Non-Rising Stem

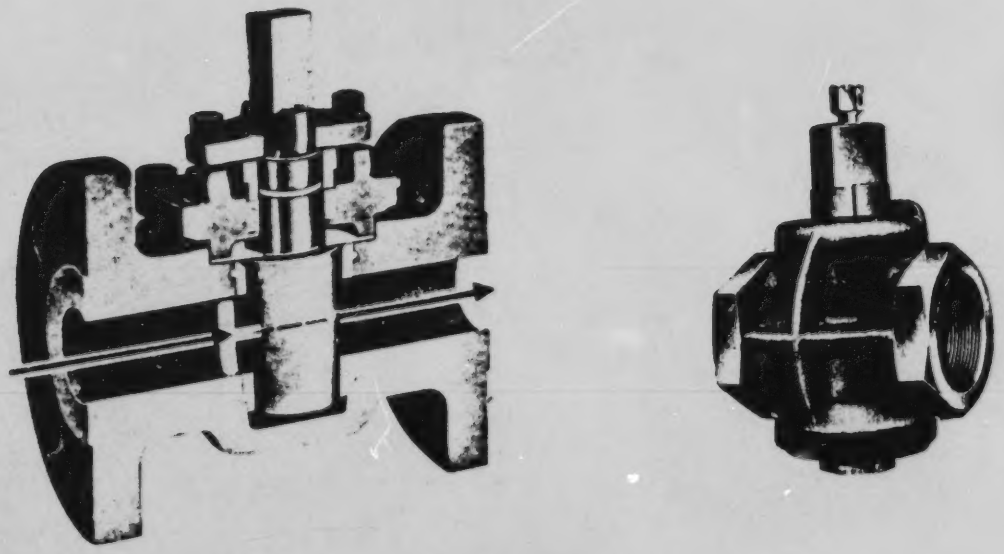


Figure 3-5 Plug Valve, cutaway and normal

3. The thread in both the nut and spindle of the valve with the non-rising spindle are exposed to the flow and are not recommended for service when the fluid is contaminated as in sewage treatment. The rising spindle valve type should be used for contaminated fluids.

4. The straight through flow characteristics of the gate valve when fully open ensures a minimum loss of head through the valve.

5. Contaminants in contact with the thread of nut and spindle in the non-rising spindle gate valve will cause seizure, unless the valve is periodically operated.

Note that a multiple thread is often employed to speed up the operating speed (closing/opening) of the gate.

Plug Valves

There are four types of plug valves also used in fully open/fully closed flow operation. They are suitable for use in high head applications. However the quick operating capability of this valve requires that a reduction gear be employed in the drive train. There are four types of plug valves:

1. Taper plug
2. Parallel plug
3. Eccentric plug
4. Ball valve

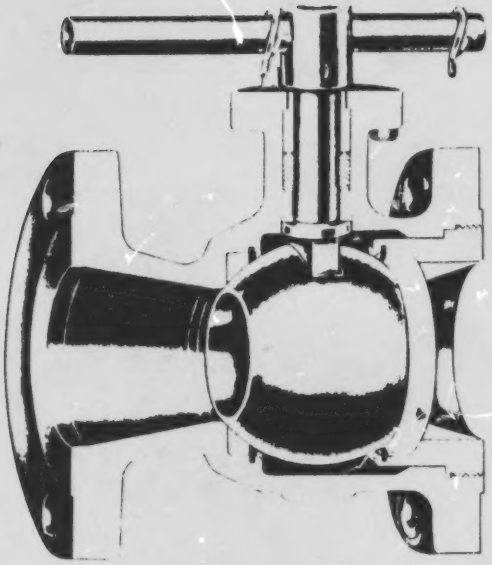
Characteristics of these types of plug valves which should be noted are:-

1. Basically there are only four parts to the plug valve, they are as follows:
   a. The body
   b. The plug
   c. The washer
   d. The nut

2. The tapered plug is not recommended for service with contaminated fluids such as sewage. Before turning, the plug must be unseated allowing grits and other particulate matter to enter the space between the two faces. The turning motion then can score both seat and plug.

3. The parallel plug valve is a disadvantage because it has to be sealed from the outside by the application of a sealing compound. Where a large number of valves are in use the maintenance of the seal may prove both expensive and troublesome. The parallel plug valve is not recommended for gas-service, unless special precautions are taken to maintain the plastic sealant.

4. The eccentric plug valve is an attempt to overcome the deficiencies of the tapered plug valve and the parallel plug valve. The design is compatible with rubber/neoprene coating and lining for use with a corrosive medium. It is recommended for service in most areas of the sewage treatment process. See cut-away model.



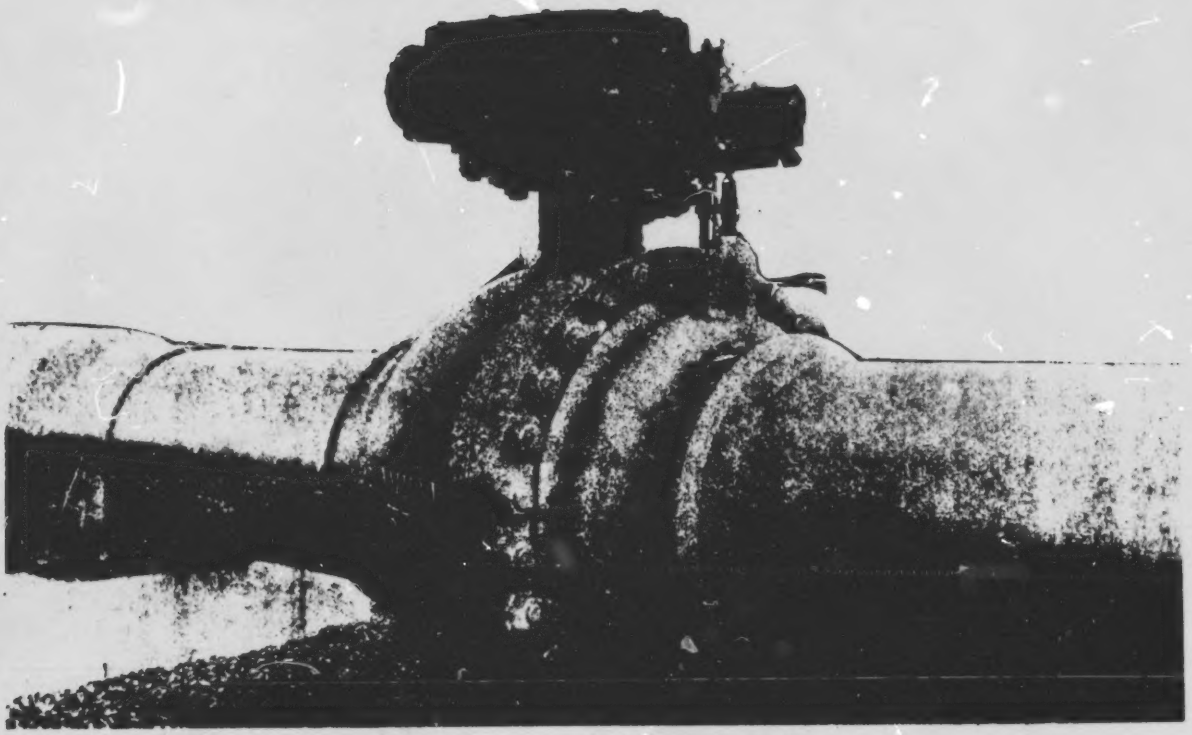


Figure 3-6 Ball Valve - Cutaway and large installation, mechanically controlled.

5. Plug valves (Fig. 3-5) can be supplied with round rectangular and diamond shaped ports. Round port valves are recommended for service where the valve opening must be equal to the diameter of the pipe, i.e. sludge and slurry pipelines. Plug valves with a rectangular port are recommended for general open/shut applications with clear mediums. Plug valves with a diamond shaped port are recommended for flow regulating service.

6. Another variation in plug valve design is the ball valve (Fig. 3-6). As the name implies a ball or sphere replaces the tapered or cylindrical plug. The ball or spherical valve is recommended for flow regulation service. In some high head, high flow, water pumping applications they are displacing the plug valve mainly because of improved performance, reliability and ease of maintenance.

Globe Valve

The globe valve (Figure 3- 7) is employed in the most common of all flow regulation applications, the faucet. It is extremely rugged and reliable and will perform for years with little or no maintenance but plenty of abuse. However, it does cause considerable head loss in a piping system due to the path the fluid must take to pass through the valve. Care must be taken to install the valve in the line so that when the valve is fully closed the pressure is contained under the seat and is not against the stem packing. Some spindles have a back seating disc that will, when the valve is fully open, protect the stem packing from the line pressure.

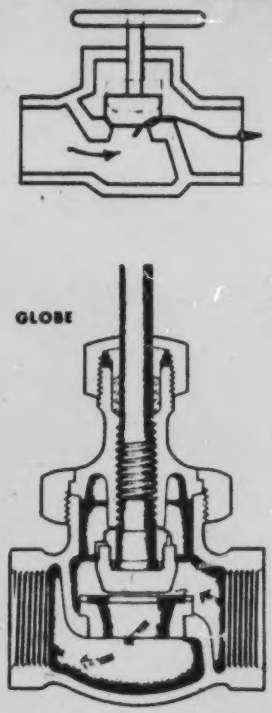


Figure 3-7
General Purpose Globe Valve

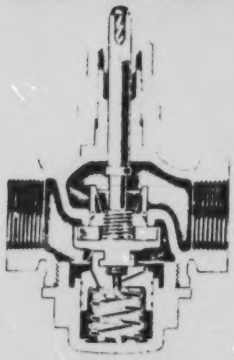


Figure 3-8

Quick Operating Globe Valve
(for use where rapid closure
is essential)

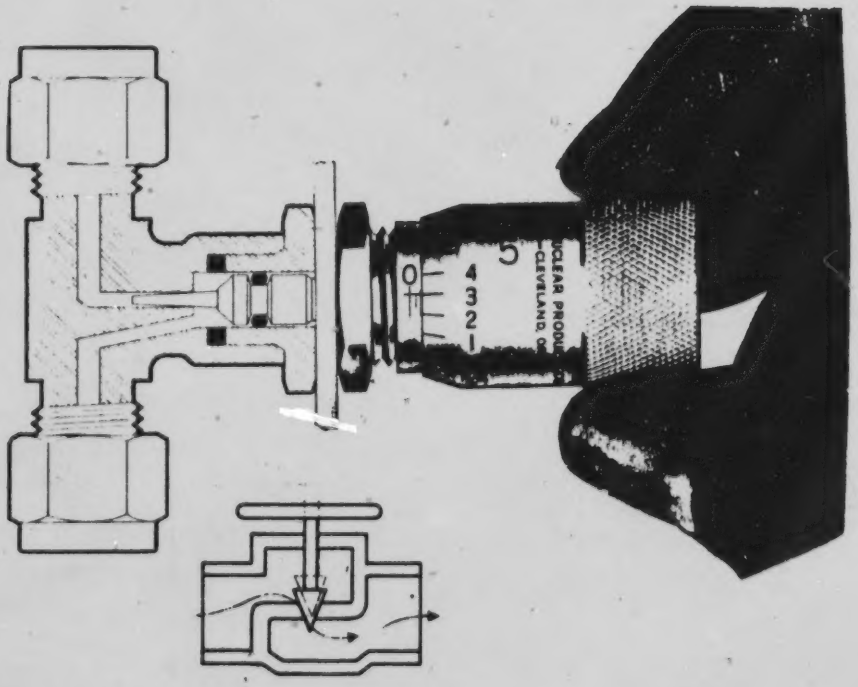


Figure 3-9 Needle Valve

Needle Valve

The needle valve (Figure 3-9) is similar to the globe valve in that it is recommended for flow regulating service but will provide greater accuracy. Inspection of Figures 3-8 and 3-9 will expose the similarities and differences between the needle and globe valve.

Figure 3-10

Quick Opening
Globe Valve

Figure 3-11

Quick Opening
Coin Action
Gate Valve

Quick-Operating Valves

The globe valve and the gate valve can be easily adapted to quick-opening/quick closing-operation. A lever is used to operate the valve in place of the usual threaded spindle and control wheel. (Figures 3-10 and 3-11). The plug valve and the butterfly valve can be used on quick-operating applications when an operating lever is directly connected to the valve spindle.

Air Horns, Emergency Showers, Emergency Eye Washers, and Emergency Gas line shutoffs are but a few examples of applications for quick-operating valves.

Butterfly Valves

Butterfly valves are manufactured for pressures of up to 150 P.S.I. and temperatures of from - 40° F to 300° F dependent upon the design and upon the materials used in construction. It is recommended for both flow regulation and for fully open/closed operation. However, some users may challenge claims to suitability for high head applications made by certain manufacturers.

Butterfly valves can be purchased with the spindle in either a vertical or horizontal plane. (Figure 3-12) will illustrate a horizontal butterfly valve.

Diaphragm Valves

Diaphragm valves are recommended for applications in which the fluid handled would be harmful to the operating mechanism. It is also suitable for corrosive service because it adapts readily to lining with a wide variety of corrosive and abrasive resistant materials. It does not require a gland and provided the diaphragm remains intact there will be no leakage between spindle and body.

The most common type of diaphragm valve operates on the principal of pinch; the elastomer diaphragm being pinched against a weir cast into the body of the valve. (Figure 3-13). A diaphragm can be used in conjunction with globe and needle valves whenever the flow of dangerous fluids must be contained within the valve body.

Figure 3-12 Butterfly Valve Vertical and Horizontal

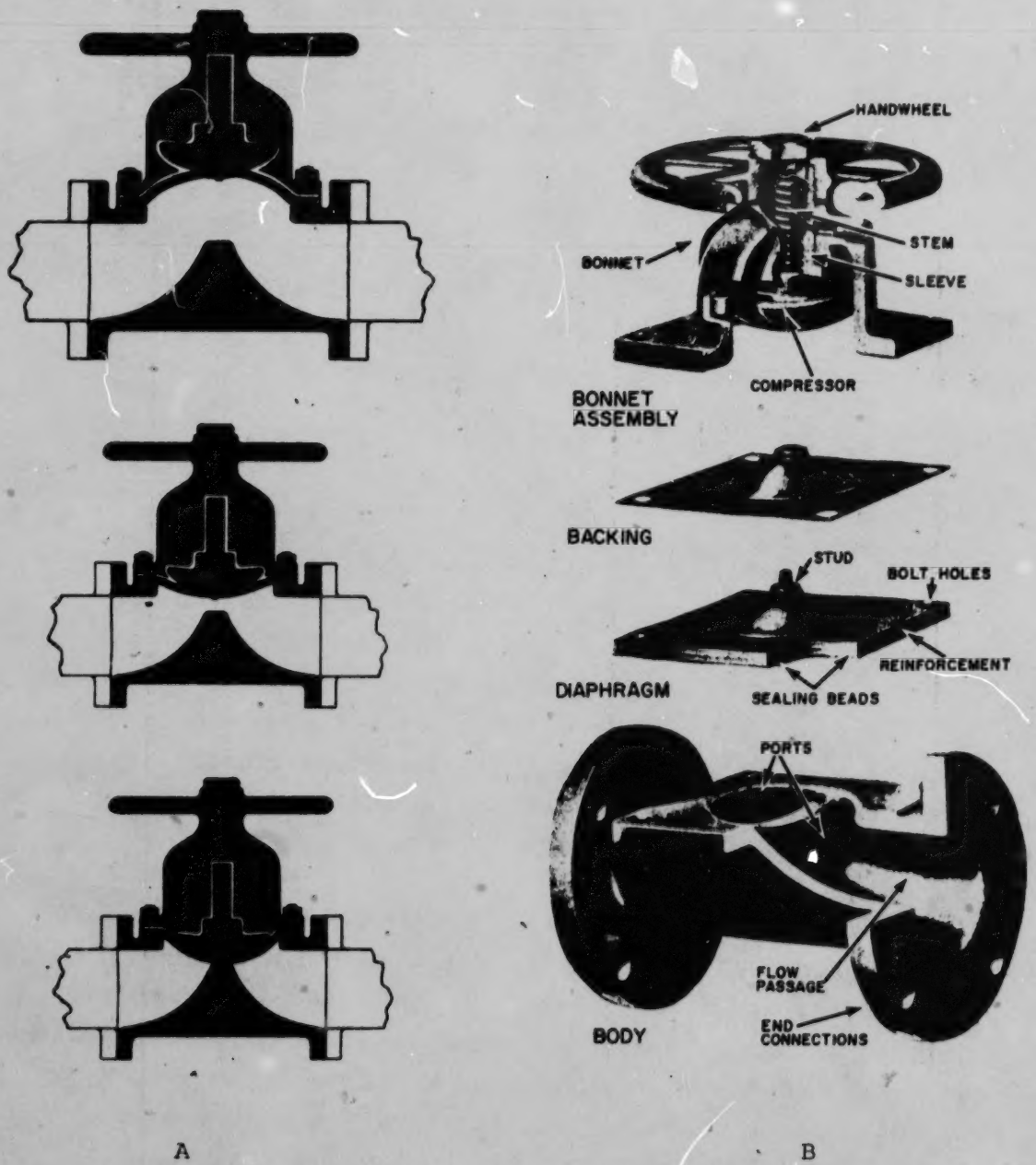


Figure 3-13 Diaphragm Valve

A - shows various positions

B - shows Blowup of Valve

Check Valves

Provision for the control of direction of flow is made by means of check valves. These include:

1. Swing check valve horizontal line (Figure 3-14)

2. Horizontal Lift Check Valve (Figure 3-15)

3. Vertical Lift Check Valve (Figure 3-16)

4. Ball Check Valve for Vertical pipeline (Figure 3-17)

5. Foot Valve installed at open end of suction pipe to prevent drainage and loss of prime (Figure 3-18)

The cross-sectional view of a swing check valve (Figure 3-15) shows that the valve is connected to the upper part of the body by a hinge. The valve swings about the hinge in response to changes in rate of flow. Whenever the flow stops and attempts to reverse direction the valve will swing into the closed position against the seat located in the body.

Whenever the swing check valve is employed in a high head/flow applications it is recommended that a "Dash Pot" be installed to prevent damage to the valve by reducing the effects of water hammer. The swing check valve has the advantage of a low loss of head through the valve, particularly under full flow conditions. It can also operate in a vertical and a horizontal position.

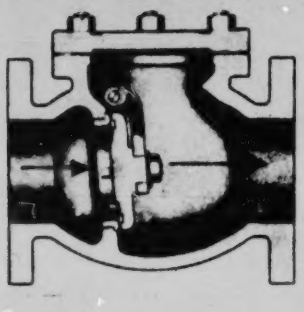


Fig. 3-14
Swing Check Valve

Fig. 3-15
Horizontal Lift Check Valve

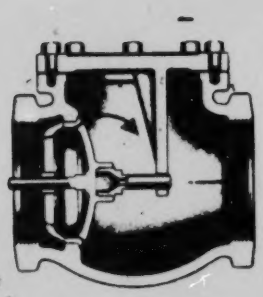


Fig. 3-16
Vertical Lift Check Valve

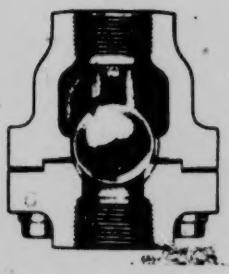


Fig. 3-16
Ball Check Valve

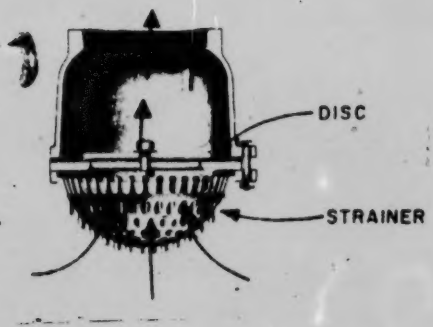


Fig. 3-18
Foot Valve

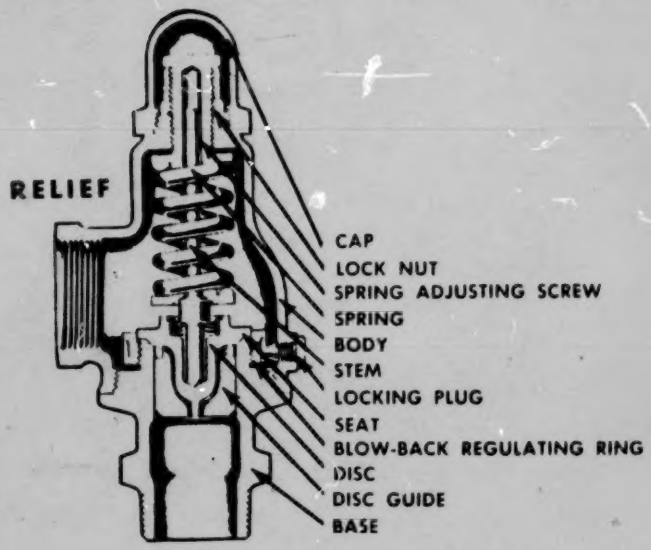


Fig. 3-20 Pressure Relief Valve
(Safety Valve)

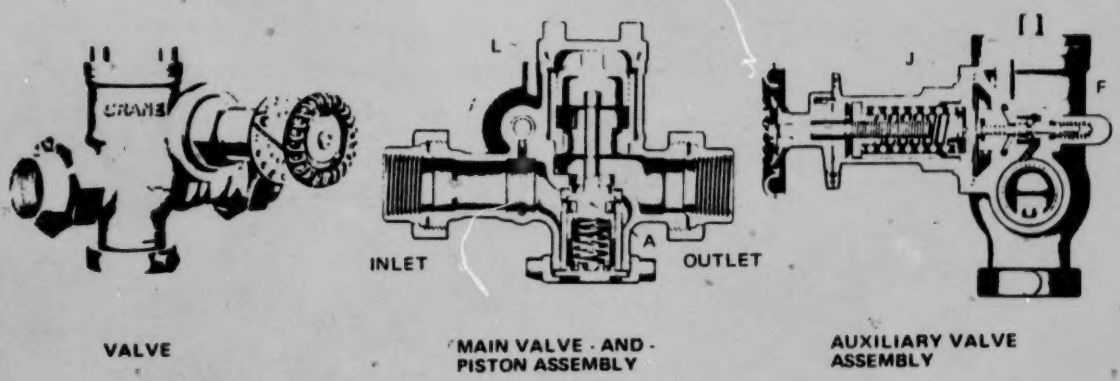


Fig. 3- Pressure Regulating Valve

Special Service Valves

Special service valves are, for the most part, simply common line valves that have been adapted to meet a special application, e.g.:

1. Pressure Relief Valve (Safety Valve) is, a globe valve with a plain, spring loaded spindle, pre-set to open and close in response to a pressure change. (Figure 3-19).

2. Pressure Regulating Valve can also be a globe valve with a plain spindle (unthreaded) capable of modulating the downstream pressure in response to variations to downstream and/ or upstream pressures. (Figure 3-20).

Operation of Valves

Line valves are operated by hand (manually), by electric motor or solenoid, by hydraulic or pneumatic powered mechanisms. Certain valves are spring operated but usually in one direction only - closing. The drive can be direct acting as with hydraulic, pneumatic cylinders or diaphragms or by means of an electric solenoid, or indirectly by use of a train of gears interposed between the valve and the driver. Control can be either local or remote, manual, or, automatically in response to signals from a monitoring source.

Method of Connection to Pipeline

Valves are connected to a pipeline by the same methods employed to connect any other pipe fitting (i.e. elbow, tee, cross branch) by screwed connection, flanged connection, compression fitting, Victaulic, soldered joint or welding.

In the case of welding, nipples and flanges should be welded to the valve to make a flanged connection to the pipeline to facilitate removal. Always bear in mind that sooner or later a valve will have to be maintained so make provision for its removal.

Provide proper support for the pipeline adjacent to the valve. Heavy valves of 8 inches or over should be directly supported.

Gate Valves located on the suction side of centri-fugal pumps should, whenever room permits, be turned so that the spindle is parallel to the ground. This will ensure that the medium being handled will keep the stem packing moist and prevent entrance of air into the pump.

The valve must be free of stress, therefore the pipeline must be properly aligned and the flange faces square. Flanges are to be tightened evenly by the proper rotation of the wrench on the flange bolts. (Figure 3-21).

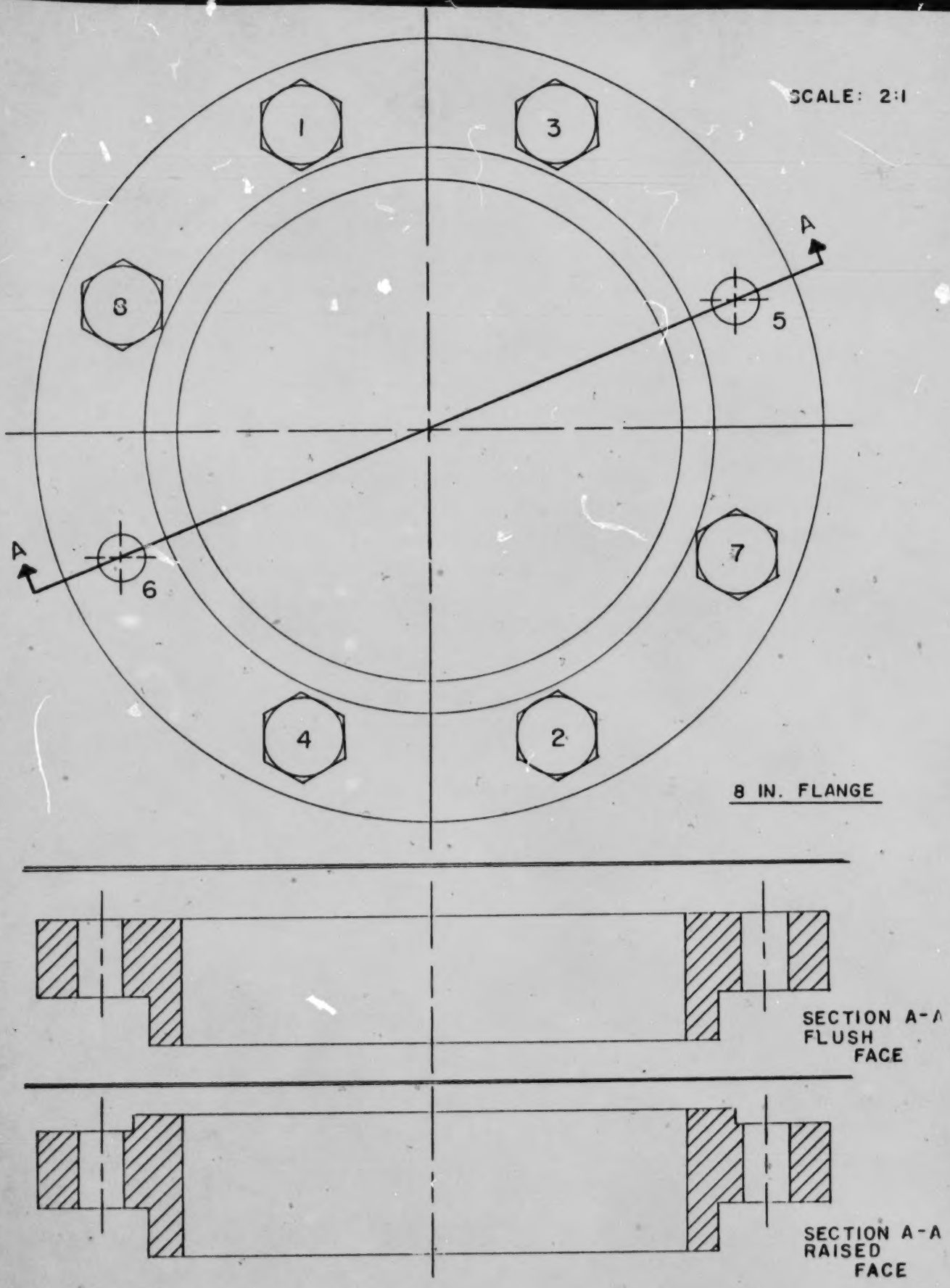


Figure 3- 21 Order of Tightening Flange Bolts

IDENTIFICATION/MAINTENANCE OF VALVES

Identification

A single equipment identification system should be capable of accommodating all types of equipment within the area of responsibility. The simplest method of identification is to use a single number or letter, i.e. 1, 2, 3 or a, b, c. This would be adequate provided that identification is limited to a few items of a single type and located in one area or employed on one process, and provided that there would be no future expansion of plant or process.

Design Engineers and Contractors quite often adopt the initials of the item plus a number as a means of identification, i.e. PV = Plug Valve; CV = Check Valve; GV = Gate Valve; GIV = Globe Valve, etc. The alphabetical identifier is suffixed by a numeral to indicate sequence. This system may be adequate for contract work, *but it is not adequate for plant operations* where the identifier may be required to identify any or all of the following:

1. Location
2. Process
3. Type of equipment
4. Sequence

Thus a simple system might for example use PV #1, where P = location or process (Primary), V = Type of equipment (Valve) and #1 = sequence number.
There are many variations of this type of code. It is simply a matter of selecting a code that will satisfy the present and future needs of the plant.

The cost of designing and implementing an identification system can be considerable, therefore the task should not be undertaken lightly or halfheartedly. The identification code should also be applied to the equipment file, drawings, manuals, history of repairs, etc. Whenever an identification code is adopted the identifier must be applied to all components of the equipment by means of a stencil decal or engraved plate. The markings must be clear and permanent and conform to the requirements of the Industrial Safety Act of Ontario and the regulations of other governing bodies, boards, etc.

Maintenance

The descriptions of the valves in the foregoing pages and the various applications for which they are recommended should have provided an insight into the maintenance requirements of valves. Prescribing maintenance requirements without a specific valve in mind, and without knowing what the manufacturer's recommendations are, or the conditions under which the valve operates, etc., can be a risky proposition. Nevertheless, there are certain aspects of preventive maintenance that can be applied to valves in general.

A few words of caution may be necessary before the question of preventive maintenance is discussed. There is a tendency for personnel, when setting up a preventive maintenance schedule, to play it safe by being overgenerous, and allow too short an interval of time between activities. Also, to schedule an unnecessary amount of work at each activity. The question to ask is, not what maintenance procedure is desirable, but rather what maintenance procedure is essential? If the preventive maintenance program is overloaded with non-essentials it will most likely fail.

Part of the routine preventive maintenance effort should be aimed at preventing the valve from seizure by the scheduled periodic opening and closing of each valve. The time interval will be dependant on several factors, i.e. the medium handled, climatic conditions (if outdoors), ambient conditions, (wet, dry, dusty, hot, cold) and severity of service. Also, the frequency with which the valve is normally operated.

For various valves and their parts see Figure 22.

1. Gate Valves: Oil Spindle at gland
   Check gland leakage
   Check flange leakage

2. Plug Valves:

   (a) Parallel plug: Replenish the sealing compound as required
   Check gland for leakage
   Check flange for leakage

   (b) Taper Plug: Replenish the sealing compound or lubricant

   (c) Ball or Spherical Plug: Check gland for leakage
   Check flange for leakage

3. Globe Valve: Check gland for leakage
   Check flange for leakage
   Oil spindle at gland

4. Diaphragm Valve: Check for leakage from bonnet at spindle (Diaphragm leaking)
   Check flange for leakage

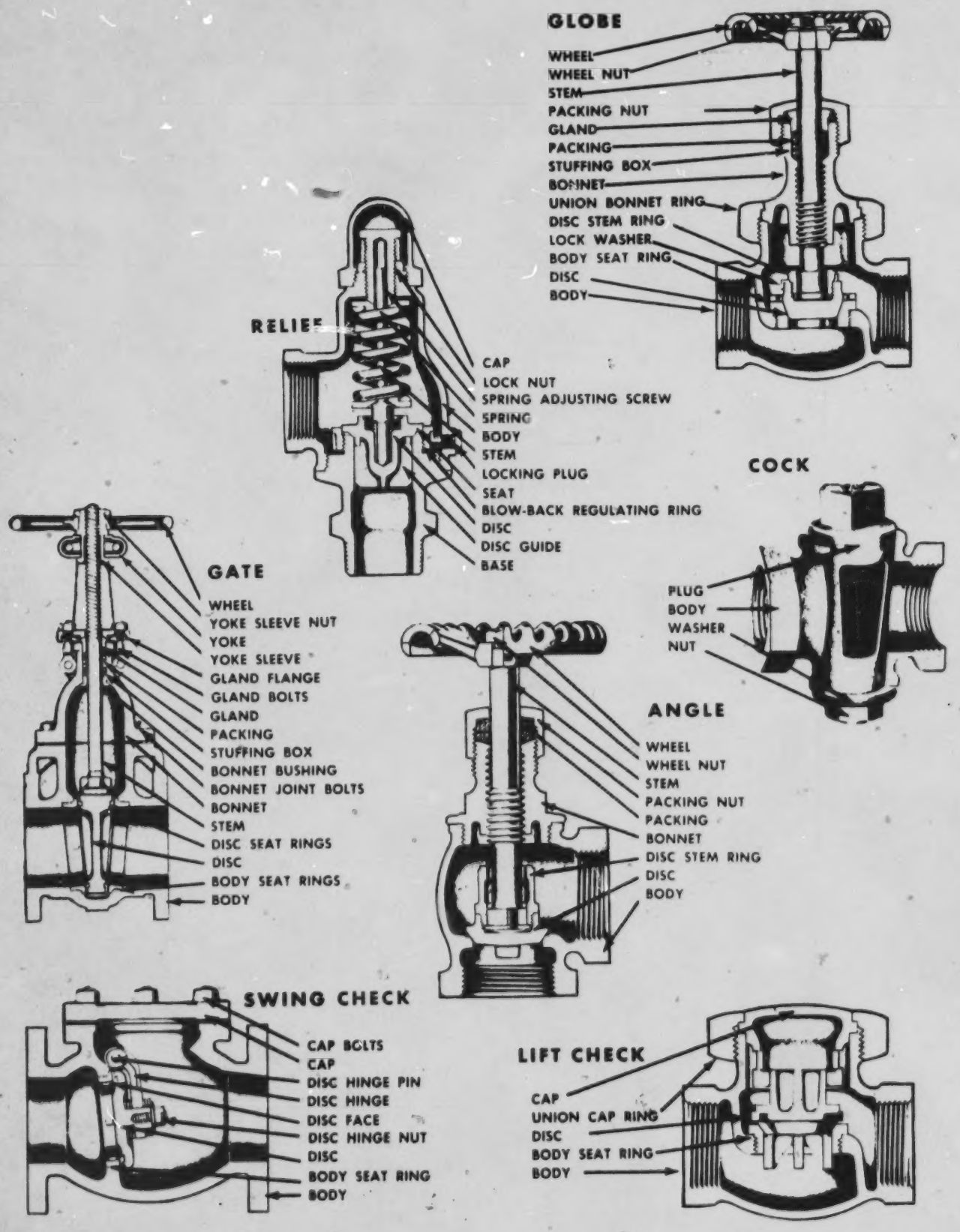


Figure 3-22 Basic Valve Designs

5. Needle Valve: Check gland for leakage
Oil spindle at gland (except for gas, oxygen - acetylene application)
Check line connections for leakage

6. Check Valve: (Non-return valve)
Check dashpot for leaks
Check trunnion seals
Check trunnion bearings
Lubricate trunnion bearing
Check flanges for leakage

In addition to the foregoing preventive maintenance recommendations, reference must be made to the Manufacturer's instruction manual and name-plate data. Safety must be the overriding factor in all maintenance activities and this rule must be applied to the material in this pamphlet.

SAFETY

In the foregoing pages little reference was made to safe working procedures for work on pipelines. Here are a few do's and don'ts on safety when working on pipeline maintenance:

1. Before opening a pipeline be absolutely certain that you know what kind of fluid the line contained.

2. Make sure that the pipeline has been drained and, whenever necessary, purged and/or vented.

3. Lock in the closed position the connecting valves on either side of the section to be opened and attach a signed and dated danger tag to each valve.

4. When opening the initial flange do so by backing off the flange fasteners sufficient to separate the two flange halfs just enough to confirm that the pipeline is not under pressure.

Never remove all the fasteners and then separate the flange halfs, to do so is to invite disaster.

5. Exercise extreme caution in your approach to pipeline maintenance:

   a. Don't be misled by so called low pressure systems, they too can pack a mighty punch for the unwary.

   b. Don't rely on others for your protection, you cannot depend on anyone but yourself.

   c. Don't take chances, if you are not sure, seek the advice of your superiors.

   d. Do wear your protective clothing and equipment. Intelligent people make use of theirs.

6. When the job is completed, notify the operator in charge. Remove padlocks and danger tags from the valves. Return tools and equipment to the respective storage areas, tag faulty tools and equipment for repair. Leave the job site in a clean, tidy and safe condition, not necessarily as you found it, but as you would have liked to have found it.

One final comment, always obey rules and regulations. They were not introduced by well meaning people with little else to occupy them. For the most part, safety rules and regulations came about as a result of the investigation of accidents in which people like you and me had been injured or even killed.

APPENDIX A

CHARACTERISTICS OF

STEEL AND WROUGHT IRON PIPE

Pipe Sizes

To the uninitiated, judging the size of a pipe can pose a problem. It does not seem to matter whether or not one measures the outside diameter (O.D.) or the inside diameter, the result does not match the so called pipe size. Why did manufacturers decide to adopt the outside diameter as the constant (nominal) dimension and the inside diameter, also nominal, a variable dimension? The answer to these questions is, according to "Grinnell", that the early pipe manufacturers made the wall of the pipe, in the smaller pipe sizes 1/8 to 12 inches, too thick. This may have been done to compensate for the questionable materials and welding processes of the time. However, whatsoever the reasons, in correcting this error they decide to remove the excess wall thickness from the inside of the pipe to avoid changing fittings, taps and dies.

To distinguish these pipe sizes from actual measured diameters, the terms iron pipe size (I.P.S.) or nominal pipe size (N.P.S.) are sometimes used. For pipe sizes larger than 12 inches, the pipe is known by its actual outside diameter. In all pipe sizes the outside diameter (O.D.) remains constant; variations in wall thickness affects only the inside diameter. To distinguish different weights and strengths of pipe, three traditional designations are used:

1. Standard Wall (STD)
2. Extra Strong Wall (XS) or Extra Heavy Wall (XH)
3. Double Extra Strong Wall (XXS) or Double extra heavy wall (XXH)

To broaden the range of wall thicknesses, schedule numbers were adopted as follows:

1. Steel Pipe
   Schedule 10 (S10) through Schedule 160 (S160).

2. Stainless Steel
   Schedule 5 (5S) through Schedule 80 (80S). The addition of the letter "S" after the schedule number identifies it as pertaining to stainless steel.

3. Wrought Iron
   Note that wrought iron pipe is not included in the schedule number specification. It is still referred to as Standard (Std); Extra strong wall (XS) and Double extra strong wall (XXS).

Wall Thicknesses

Weights of carbon steel pipe are based on a density of 0.2833 pounds per cubic inch; for wrought iron pipe the density is 0.2777 pounds per cubic inch. Since wrought iron pipe is made to the same outside diameters and the same weights per foot as steel pipe, the wall thicknesses of wrought iron pipe are necessarily slightly greater than that of steel pipe to compensate for this difference in densities.

Materials

The majority of pipe is made from carbon steel in a wide variety of chemical compositions and methods of manufacture. Carbon Steel pipe, in some specifications, is available in either GRADE 'A' or GRADE 'B'. Due to a

higher carbon content, Grade B has a higher tensile strength than Grade A, but is less ductile. Generally, Grade B can be used in place of Grade A, but Grade A cannot be substituted on applications requiring Grade B pipe.

Wrought iron differs from all other ferrous metals in that it consists of highly refined iron and iron silicate, a particular type of glass-like slag. These two components are in physical association as contrasted to chemical or alloy relationship. The iron silicate, 1% to 3% by weight, is distributed throughout the iron base metal in the form of threads or fibres which extend in the direction of rolling. The combined influence of the pure iron base metal and the iron silicate confers on wrought iron the following characteristics:

1. Resistance to corrosion
2. Resistance to the effects of shock and vibration
3. Adherence of protective coatings
4. Weldability
5. Workability - forging, machining and threading

Pressure Ranges

Due to the fact that the outside diameter (O.D.) of threaded pipe remains constant for different schedule numbers and pressure ranges, it is possible for a low pressure (125 lbs.) standard fitting or a length of low pressure pipe to be inadvertently installed in a high pressure pipe network. A great deal of damage to persons and property could result from this kind of mistake. A comparison of the respective pressure ranges will underline the validity of the foregoing statement.

125 lbs. Standard Fitting. Maximum working pressures:

1. Saturated Steam 150 pounds per square inch gauge (P.S.I.G.)
2. Lower temperature fluid or gas. 300 P.S.I.G.

300 lbs. Fittings

1. ⅛ to 1 inch (NPS) or (IPS) 2000 PSIG.
2. 1¼ to 2 inch(NPS) or (IPS) 1500 PSIG.

In an effort to avoid mistakes, the following preventive measures are suggested:

1. Identify high pressure piping systems.

2. Clearly identify pipe and fittings when in storage. If possible, provide separate storage for high pressure pipe and fittings.

3. Provide training for personnel on the different classifications of fittings and pipe.

4. Designate personnel who by reason of position, training and ability are rated by you as competent to work on high pressure systems.

5. Establish safe working procedures for the operation and maintenance of high pressure systems.

6. Do not take for granted the fact that everyone in your organization is aware of these critical difference.

APPENDIX B

METHODS OF PIPE MANUFACTURE

Butt Welded

This is the oldest method of manufacturing iron/steel pipe. A heated (2600^0F) skelp of a width which will produce the required outside diameter of pipe being made is drawn through a hollow funnel-shaped die. As the skelp is drawn through the die, it is gradually cruved in the form of a tube. The edges of the skelp being forced firmly together form a weld. The hot tube is passed through sizing rolls for uniform outside diameter, descaled, resized and cut to length.

Continuous Welded

This differs from butt welded only in that the skelp is flash welded end to end to form a continuous ribbon of steel. By this method pipe can be produced at a rate of 300 to 500 feet per minute.

Seamless Pipe

A solid round billet of proper length and diameter is heated to forging temperature (2600^{O}F) and centre punched. It is then moved into a space between two piercing rolls set apart approximately 3/4 inch less than the diameter of the billet. The axis of the rolls are such that the billet, while being rotated, is moved forward over a piercing point attached to a fixed mandril.

When the billet has passed through the rolls the mandril is withdrawn and the hollow shell is returned to the furnace for reheating and further rolling and finishing operations until the final pipe size is reached.

Lap-Welded

The lap welding process is generally limited to pipe sizes 2 to 12 inches diameter. Only a few manufacturers still have lap welding furnaces.

A skelp of proper width for a given pipe diameter is heated and passed through a set of scarfing rolls where the edges are bevelled so that when they are overlapped the thickness of the finished wall will be uniform. The skelp is then drawn through bending dies to form a tube with the bevelled edges overlapping each other. After reheating to welding temperature the tube is passed through pressure rolls which force the two bevelled edges together forming a weld.

Cold Drawing

It is not practical to produce pipe to close tolerances by hot working methods. Better surface finishes, higher tensile strength and close tolerances are produced by the cold drawing process.

Seamless tubes, previously pointed at one end are pickled, washed and coated with a lubricating solution. From this point on the process is similar to the process for hot drawing seamless pipe except, of course, for the

temperature difference and the need for far more power. More than one pass through the dies may be necessary depending on the reduction in the cross sectional area that is required. The tube is annealed, pickled, washed and lubricated between each drawing.

After the final pass the tube is annealed or heat treated and cut to size. Finally the tube is protected against corrosion by a coating of lubricating lacquer or varnish. Unfortunately, a restriction of time and space allows for only a brief study of pipe manufacturing methods. There are other methods, some in use, some are under development; most, however, are variations of the five methods described in this text.

SUBJECT: PREVENTIVE MAINTENANCE

TOPIC: 4 LUBRICATION

OBJECTIVES:

The trainee will be able to:

1. Recall the functions of a lubricant.

2. Recall the important aspects of storage and handling of lubricants.

3. Recall the explanation of the following characteristics of oil:

   (a) viscosity
   (b) pour point
   (c) oxidation resistance
   (d) water separation
   (e) oil type
   (f) flash point

4. Recall the explanation of the following characteristics of grease:

   (a) hardness
   (b) pumpability
   (c) dropping point
   (d) water resistance
   (e) stability

LUBRICATION

PURPOSE OF LUBRICATION

The main functions of a lubricant are to reduce *friction* and *wear* .

Friction is resistance to motion which arises when a surface slides on another surface.

Wear is any loss or destruction of the surface as a result of the sliding.

To understand how a lubricant reduces wear, imagine two blocks with smoothly ground surfaces, one on top of the other. If we pull on the top block with a certain force, we find it requires a pull of perhaps 15 lbs. to move the top block. However, by placing some oil between the blocks, we find that a pull of only 2 1/2 lbs. is required to slide the top block. The oil has reduced the friction between the two blocks.

What causes friction? If one were to look at the surfaces of the steel under a powerful microscope, one could detect a definite roughness or minute peaks and valleys. This is what prevents easy sliding. However, when oil is present between the blocks, the blocks are separated and the small peaks and valleys can no longer interlock. The top block slides very easily over the bottom block.

What causes wear: Many clean metal surfaces tend to stick together if brought into direct contact. Usually air, grease or oxide interfere with establishing this contact. However, as surfaces rub together, the masking films may be torn away momentarily. The areas of metal thus freshly exposed to direct contact will tend to cling together or even weld fast. This sets up a resistance to

sliding motion. Since wear is usually associated with friction, the high areas of the two surfaces rub each other. This wearing process tears away fragments and the surface becomes rougher and the rate of wear increases and the loosened fragments may hasten wear by scratching and gouging the surfaces.

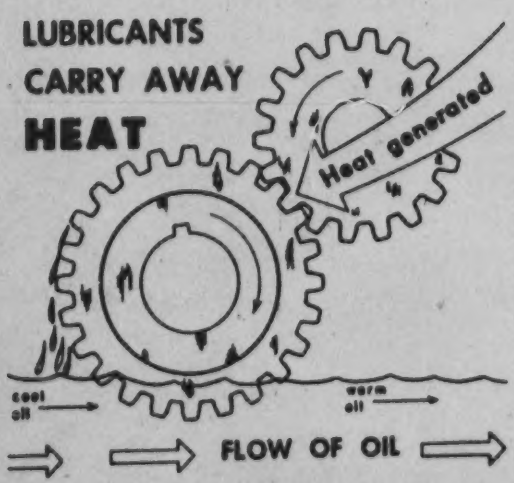
Friction and wear cannot be eliminated but can be reduced by the use of the correct lubricant.

Other Important Functions of Lubricants

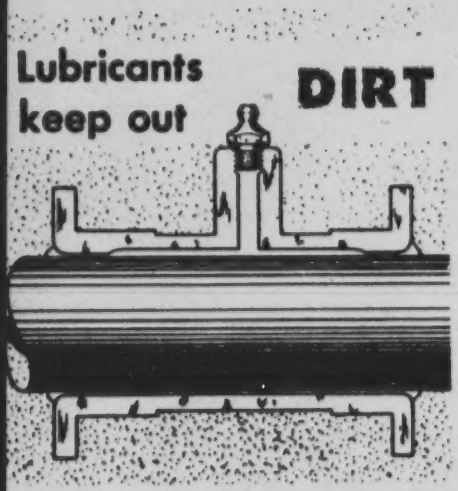
1. To carry heat away from bearings and running parts.

a) Carry away Heat (Oil)

Another function of liquid lubricants is that of carrying away HEAT. Heat in a machine is developed at the points of contact between the rubbing and rolling part, by the medium handled (hot water) and as a result of rolling friction within the lubricant. In some circulating systems, the hot oil is carried off to coolers and then returned for another cycle. In some systems, the heat eventually passes from the oil, through the sides of the oil reservoir, and into the air. Therefore, it is normal for the oil in reservoirs to become heated when the machinery operates, but EXCESSIVE heating of the oil is a danger signal that calls for an inspection of the machine and the lubricant to determine the cause of the excess heat.



2. To aid in sealing against dirt.



a) Keep out Dirt (Grease)
The proper use of a lubricant will keep the bearing clean. In this drawing, the sleeve bearing has been filled with grease and the excess has come out at the ends to form a seal around the shaft. Each time a new addition of grease is applied at the middle of the bearing, it replaces the lubricant, cleanses the bearing and maintains the seal.

3. To protect metal surfaces against rust and corrosion.

STORAGE AND HANDLING

Proper storage and handling of lubricants is essential to good maintenance. Every plant, regardless of its size, should have a definite place for storage of oils and greases, even if it is only in a designated corner. Larger facilities should have a centrally located oil storage-house or a special room. This room or building should be of fire-proof construction, with brick or concrete walls, steel beams and a metal or concrete roof.

Exposed heating devices should be placed so that it is impossible to store lubricants against them. Wide fluctuation of temperatures should be avoided since it can lead to condensation of moisture within the lubricant containers. Approved fire extinguishers should be readily available.

Cleanliness and orderliness are two prerequisites for oil storage. The storage area should be organized, i.e. racks for oil drums, space for grease drums, shelves for

smaller containers and an especially clean area or cupboard for oil cans, grease guns, etc. A closed metal container must be provided for discarded oily rags, etc.

Lubricant containers should be kept clean on the outside and lubricant pumps, measuring cans, grease guns, etc., should be stored away from open windows to avoid contamination from dirt, dust or other foreign objects. When oil drums are stored on end, it is important to see that water does not get inside through loose or open bung holes. *If paddles are used to scoop grease from the container they should be of metal fabrication.*

CHARACTERISTICS OF LUBRICANTS

Proper lubrication has been defined as the use of the right lubricant in the right amount at the right place at the right time.

In selecting the proper lubricant, the design of a machine and its operating conditions must be considered. Among the facts necessary to consider are:

1. Recommendations of the lubricant manufacturer.
2. Method of lubrication.
3. Operating speed and load.
4. Type of bearings.
5. Operating and ambient temperature.
6. Frequency of lubrication.

The following paragraphs discuss the characteristics of oil and grease which are considered when selecting a particular lubricant.

OIL

The characteristics of an oil of importance in lubricant selection are:

1. Viscosity
2. Pour Point
3. Oxidation Resistance
4. Water Separation
5. Oil Type
6. Flash Point

Viscosity

VISCOSITY is the measure of flowability or thickness of a liquid, at definite temperatures. Low-viscosity oils, often referred to as light oils, flow freely. High-viscosity or heavy oils, flow slowly. Oils having viscosities between these extremes are called medium-viscosity oils. See Figure 4-1.

In general, heavy oils are used on parts moving at slow speeds under high pressure, since the heavy oil better resists being squeezed out from between the rubbing parts. Light oils are used when higher speeds and lower pressures are encountered, as they do not impose as much drag on high-speed parts and the high speed permits a good oil wedge to form even though the oil is light. Low temperatures call for light oils and high temperatures are more apt to demand the heavier oils because oils increase in viscosity as their temperatures become lower and decrease in viscosity as the temperatures go up. An exception to this is multi-grade oil.

Pour Point (Figure 4-2)

Pour point is another property of oil that is particularly important if the oil is to lubricate machinery operated in unheated buildings or outdoors during cold weather. The pour point of oil is the lowest temperature at which it will pour, or flow when chilled without disturbance. Even as water loses its fluidity and becomes solid at a certain temperature, so, too, does oil cease to flow. Some oils with high pour points will stop flowing at 40°F whereas others with low pour points will still flow freely in temperatures below zero.

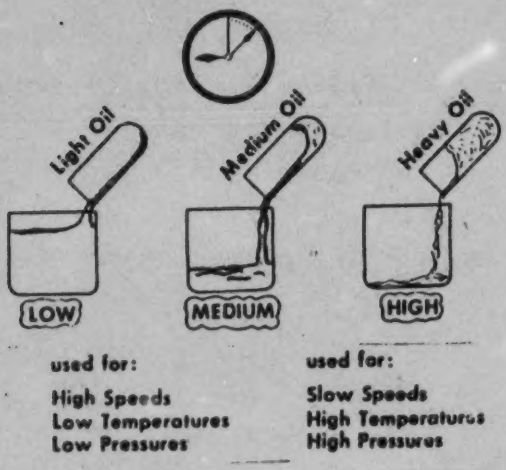


Figure 4-1 Viscosity

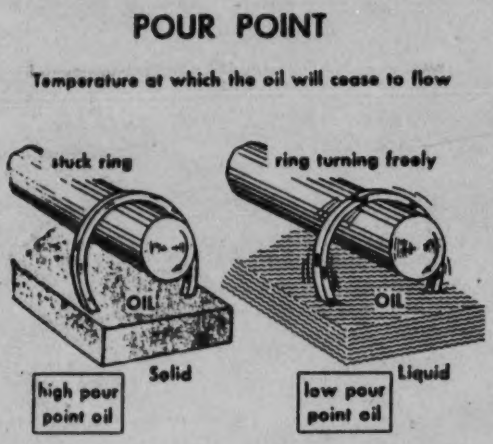


Figure 4-2 Pour Point

Oxidation Resistance

Oil is a complex mixture of compounds of hydrogen and carbon called hydrocarbons. When hydrocarbons are exposed to air and heat, they combine slowly with the oxygen in the air and are chemically changed into materials unsuitable for use as lubricants. The slow combination of oil with oxygen is called oxidation, and the materials formed are called the products of oxidation.

While oxidation occurs slowly when oils are in service, churning and splashing of the oil and exposure of the oil to temperatures much above room temperature hastens oxidation. Turbines and large circulating systems, in which oil is used for long periods without being changed, must have oils with high resistance to oxidation. These are more expensive because their refining costs are higher. Where oil remains in service only a short time, or new oil is frequently added to make-up, those grades with lower oxidation resistance may serve satisfactorily.

Water Separation (Fig. 4-3)

When water enters and is churned up with oil, an emulsion is formed which has poor lubricating properties. If the oil is clean, it will separate from the water if it is allowed a rest period. This characteristic is known as demulsibility. Demulsibility of the oil is good if it separates quickly and poor if it separates slowly.

It should be noted here that the presence of products of oxidation may slow down or stop this separating process.

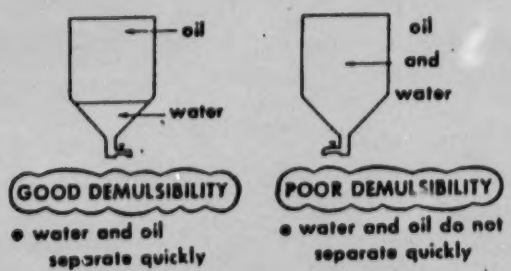


Figure 4-3 Water Separation

Oil Type

Extreme-pressure oils are used on gears and bearings that operate under extreme loads and pressures. With extreme shocks and pressures, moving steel parts may break through an ordinary oil film and establish steel-to-steel contact. The EP (extreme pressure) oils contain added ingredients that help prevent metal-to-metal contact wven if the oil film itself should fail to maintain the necessary separation.

Oils lubricating the insides of steam cylinders are exposed to both heat and water. These oils have an animal-fat oil to them to assist them in maintaining a lubricating film on the hot, wet walls of the steam cylinder. Such a fatty oil is called a COMPOUNDED OIL.

Oils used to lubricate internal combustion engines and air compressor cylinders have a detergent (cleaning agent) added to them which helps keep deposits from forming on the piston rings and other surfaces in contact with the oil. Such an oil is known as a DETERGENT OIL.

Excessively loaded gears
need Extreme
Pressure Oil (E.P. Oil)

Steam Cylinders
need Compounded Oil

Diesel Engine
crankcase lubrication
calls for Detergent Oil

Flash Point

Flash point is the lowest temperature at which there are sufficient "vapours" to cause an explosion.

GREASE CHARACTERISTICS

The characteristics of grease which will be considered are:-

1. Hardness
2. Pumpability
3. Dropping Point
4. Water Resistance
5. Stability

Hardness

Hardness, sometimes known as consistency or penetration, is a measurable characteristic of grease that must be considered in selecting a suitable grease for a particular lubrication job. No. 0 grease is soft, the hardness increasing to No. 1 and No. 2 and so on up to No. 6, which has the consistency of a cake of soap. Just as the soil in your garden is hard if a spade barely enters it and soft if it spades easily, so grease hardness is determined and graded according to the depth to which a sharp, pointed cone will penetrate the grease when dropped from a certain height.

Pumpability

Another important characteristic of a grease is the ease with which it can be pumped. For example, in centralized grease systems, the pump must develop sufficient pressure to force the grease through the lines and through the small passages in the numerous distribution valves to the machine bearings.

Two different greases that may be pumped with equal ease at ordinary room temperature will often differ widely in pumpability at a much lower temperature. The pressure gauge on the centralized system may show that the pump builds up a pressure of 1,000 psi when pumping grease (a), whereas a pressure of 2,000 psi is required to pump grease (b). The difference is due to the kinds and proportions of oils and soaps in the composition of the two greases.

A centralized grease system is designed for operation within a definite pressure range that should not be exceeded. Therefore, grease pumpability is of very real importance.

Dropping Point

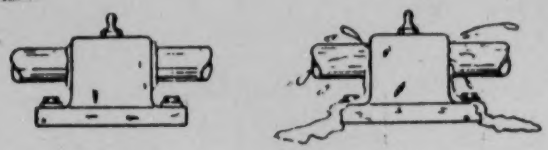
Different greases melt at different temperatures because of the soaps they contain. The DROPPING POINT of a grease is the temperature at which it passes from a semi-solid to a liquid. Most calcium (lime) soap greases melt in the 160-210°F range. Sodium soap greases melt in the 275-350°F range, whereas lithium soap greases melt in the 350-400°F range. For this reason, sodium and lithium soap greases are usually used where it is known that temperatures will be high.

Water Resistance

Some greases have to do a lubrication job in spite of contact with water, so that water resistance is an important property of greases. Greases with calcium and lithium soaps will not dissolve in water, but soda-soap greases are not used where there is a possibility that water will contact the lubricant. Fine, powdered graphite is added to some greases to improve their performance on plain bearings in the presence of water.

Stability

Some greases, when placed in a bearing, will retain their original hardness; that is, they are stable. Such greases will stay in antifriction bearings very well and give good lubrication for a long time. Other greases lose their hardness after being worked in a bearing for some time and become quite soft. They may even run out unless the bearing is very well sealed. Obviously, the type of grease that retains its hardness and stays in the bearing is the more desirable. Such a grease is said to have good stability. See Figure 4-4.



GOOD
Grease Stays in the Bearing

POOR
Grease Thins and Runs Out of the Bearing

Figure 4-4 Stability

Lubrication Chart

Because of the many differences in the properties of lubricants and in the machines to be lubricated, considerable knowledge and study are necessary to select the proper lubricant for a particular machine. The eventual choice is based on the specifications of the equipment manufacturer, the recommendations of the lubricant manufacturer and the particular conditions under which the machine will operate.

Lubrication charts or records should be prepared and kept up-to-date for all the different items of equipment. The chart should list the different parts of a machine to be lubricated, the method of application, and the type of lubricant to be used. If applicable, the frequency of lubrication should be recorded.

The worst problem in industry today is not due to lack of grease, but too much grease. The theory is if one shot is good, five shots are better. This is totally incorrect. Test the bearing with your hand. If cool leave alone, it is okay. If not and it has been greased recently, remove plug or grease fitting to release excess grease.

SUBJECT: PREVENTIVE MAINTENANCE

TOPIC: 5 BEARINGS

OBJECTIVES:

The trainee will be able to:

1. Recall the various types of bearings and their functions.
2. Recall the importance of cleanliness.
3. Recall procedures of mounting and dismounting.
4. Recall the considerations of variable temperature conditions for the different types of bearing applications.
5. Recall the lubrication factors for bearings.
6. Recall the common causes of bearing failures.

BEARING TYPES AND THEIR FUNCTIONS

Designers have a wide variety of bearing types from which to choose. Each bearing type has characteristics which make it the best choice for a certain application. The original selection is made to assure maximum bearing performance. Therefore, a replacement should conform to the manufacturers specifications. The following resume of the functions of each bearing type will aid you to better serve your replacement field. See Figure 5-1.

1. Self-Aligning Ball Bearings

   The self-aligning ball bearing, with two rows of balls rolling on the spherical surface of the outer ring, compensates for angular misalignment resulting from errors in mounting, shaft deflection and distortion of the foundation. It is impossible for this bearing to exert any bending influence on the shaft, a most important consideration in applications requiring extreme accuracy, at high speeds. Self-aligning ball bearings are recommended for radial loads and moderate thrust loads in either direction.

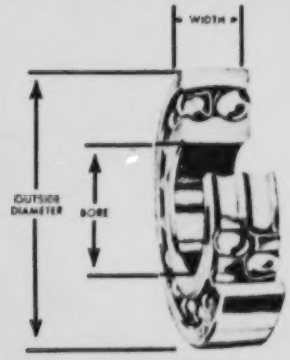
2. Single Row, Deep Groove Ball Bearings

   The single row, deep groove ball bearing will sustain, in addition to radial load, a substantial thrust load in either direction, even at very high speeds. This advantage results from the intimate contact existing between the balls and the deep, continuous groove in each ring. When using this type of bearing, careful alignment between the shaft and housing is essential. This bearing is also available with seals and shields, which serve to exclude dirt and retain lubricant.

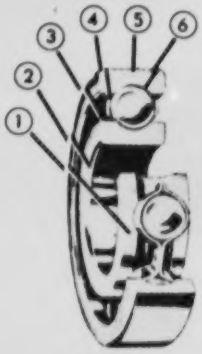
BEARING NOMENCLATURE

The illustrations below identify the bearing parts of the nine SKF basic bearing types. The terms used conform with the terminology section of the AFBMA* Standards—and are mutually accepted by the anti-friction bearing manufacturers.

*Anti-Friction Bearing Manufacturers Association, Inc.



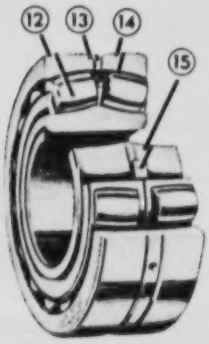
Self-Aligning Ball Bearing



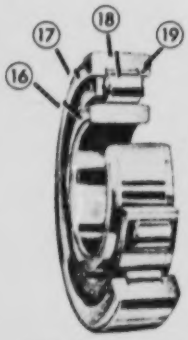
Single Row Deep Groove Ball Bearing

Angular Contact Ball Bearing

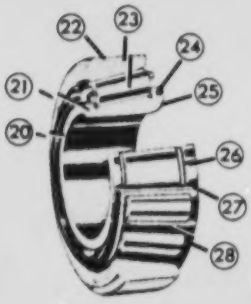
Double Row Deep Groove Ball Bearing



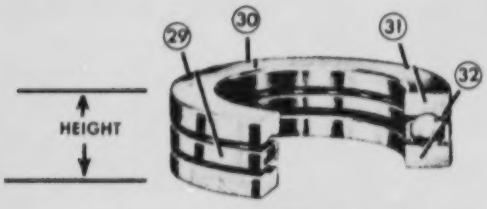
Spherical Roller Bearing



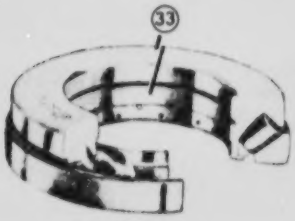
Cylindrical Roller Bearing



Tapered Roller Bearing



Ball Thrust Bearing



Spherical Roller Thrust Bearing

1. Inner Ring
2. Inner Ring Corner
3. Inner Ring Land
4. Outer Ring Land
5. Outer Ring
6. Ball
7. Counter Bore
8. Thrust Face (Face)
9. Outer Ring Raceway
10. Inner Ring Raceway
11. Outer Ring Corner
12. Spherical Roller
13. Lubrication Feature
14. Spherical Outer Ring Raceway
15. Guide Ring
16. Inner Ring Side
17. Outer Ring Side
18. Cylindrical Roller
19. Locating Rib
20. Cone Front Face
21. Cone Front Face Rib
22. Cup (Outer Ring)
23. Tapered Roller
24. Cone Back Face Rib
25. Cone Back Face
26. Under Cut
27. Cone (Inner Ring)
28. Cage
29. Ball Cage
30. Face
31. Small Bore Washer
32. Large Bore Washer
33. Sleeve

Figure 5-1 Bearing Nomenclature

3. Angular Contact Ball Bearings

The angular contact ball bearing supports a heavy thrust load in one direction, sometimes combined with a moderate radial load. A steep contact angle, assuring the highest thrust capacity and axial rigidity, is obtained by a high thrust supporting shoulder on the inner ring and a similar high shoulder on the opposite side of the outer ring. These bearings can be mounted singly or, when the sides are flush ground, in tandem for constant thrust in one direction; mounted in pairs, also when sides are flush ground, for a combined load, either face-to-face or back-to-back.

4. Double Row, Deep Groove Ball Bearings

The double row, deep groove ball bearing embodies the same principle of design as the single row bearing. However, the grooves for the two rows of balls, may be so positioned that the load lines through the balls have either an outwardly converging or an inwardly converging contact angle. This bearing has a lower axial displacement than occurs in the single raw design....substantial thrust capacity in either direction....and high radial capacity due to the two rows of balls.

5. Spherical Roller Bearings

The spherical roller bearing, due to the number, size and shape of the rollers, and the accuracy with which they are guided, has unexcelled capacity. Since the bearing is inherently self-aligning, angular misalignment between the shaft and housing has no detrimental effect and the full capacity is always available for useful work. The design and proportion are such that, in addition to radial load, heavy thrust load may be carried in either direction.

6. Cylindrical Roller Bearings

The cylindrical roller bearing has high radial capacity and provides accurate guiding of the rollers, resulting in a close approach to true rolling. Consequent low friction permits operation at high speed. Those types which have flanges on one ring only, allow a limited free axial movement of the shaft in relation to the housing. They are easy to dismount even when both rings are mounted with a tight fit. The double row type assures maximum radial rigidity and is particularly suitable for machine tool spindles.

7. Ball Thrust Bearings

The ball thrust bearing is designed for thrust load in one direction only. The load line through the balls is parallel to the axis of the shaft, resulting in high thrust capacity and minimum axial deflection. Flat seats are preferred... particularly where the load is heavy...or where close axial positioning of the shaft is essential; as for example, in machine tool spindles.

8. Spherical Roller Thrust Bearings

The spherical roller thrust bearing is designed to carry heavy thrust loads, or combined loads which are predominantly thrust. This bearing has a single row of rollers which roll on a spherical outer race with full self-alignment. The cage, centered by an inner ring sleeve, is constructed so that lubricant is pumped directly against the inner ring's unusually high guide flange. This ensures good lubrication between the roller ends and the guide flange. The spherical roller thrust bearing operates best with relatively heavy oil lubrication.

9. Tapered Roller Bearings

Since the axes of its rollers and raceways form an angle with the shaft axis, the tapered roller bearing is especially suitable for carrying radial and axial loads acting simultaneously. A bearing of this type usually must be adjusted toward another bearing capable of carrying thrust loads in the opposite direction. Tapered roller bearings are separable - their cones (inner rings) with rollers and their cups (outer rings) are mounted separately.

MOUNTING OF BEARINGS - SHAFTS AND HOUSINGS

Mounting Designs

The successful application of a ball or roller bearing depends to a great degree on two factors:

1. the mounting design
2. the accuracy of the various machines surfaces upon which the bearing is supported.

Unless care is exercised in both designing the bearing mounting and machining the various parts, a premature failure may result. This is true, even though the capacity of the bearing specified may be well above the applied load.

The narrow width of a ball or roller bearing provides a comparatively small surface area for the applied load. Hence, the unit pressures are high and must be uniformly distributed to the supporting surfaces of both the shaft and the housing. Therefore, it is evident that both the inner and outer rings must be properly mounted on the shaft and in the housing respectively. Serious distortion is eliminated and uniform distribution of the load is obtained.

This same care must also be used with respect to the pedestal on which the bearing housing is mounted. Distortion of the bearing housing will occur, unless the pedestal is firm and the surface straight.

A bearing housing should be designed to permit a simpliied assembly and disassembly of the component parts. Such design should also provide for simple methods of casting, with few machined surfaces - to reduce costs to a minimum.

Cleanliness

The importance of protecting the bearing from the intrusion of dirt and other foreign matter cannot be over emphasized. Seals must be designed to prevent the entrance of any type of foreign matter to the bearing. Dirt will act as a perfect lapping compound and will grind the bearing surfaces. This will result in excessive wear of the rolling elements and of the inner and outer rings. In addition, foreign matter will contaminate the lubricant - and gradually break down to oil or grease to the point where effective lubrication cannot be obtained. Dirt will also cause noisy operation.

The cavity in the housing around the bearing should be large enough to provide for an adequate amount of lubricant. Seals should be effective in retaining the lubricant in the housing.

Mounting and Dismounting

Bearings may be mounted directly on the shaft or on tapered adapter sleeves.

When mounted directly on the shaft, the inner ring should be located against a shaft shoulder of proper height. (Refer to bearing manufacturer's specifications). This shoulder must be machined square with the bearing seat and a shaft fillet should be used. The radius of the fillet must clear the corner radius of the inner ring. This also applies when mounting the outer ring in the housing. Generally speaking, bearing applications have a rotating inner ring with a stationary load applied to the bearing. In such cases, it is necessary to mount the inner ring with a press fit on the shaft - and the outer ring with a slip fit in the housing.

Creeping will occur when the inner ring is loose on the shaft. This will result in overheating, excessive wear and contact erosion between the shaft and the inner ring. The explanation of creeping action can be simplified by the use of this comparison. Compare the action of an internal gear in mesh with a planet pinion. If the planet pinion (representing the shaft), had one tooth less than the internal gear (representing the bearing inner ring), the latter would slip back on e gear tooth in each full revolution of the shaft. Hence, the speed of the shaft (planet gear) would be greater than the speed of the inner ring (ring gear) - and sliding would take place.

Therefore, it is an obvious conclusion that a preventive measure must be taken to eliminate creeping and its harmful results. Mount the inner ring with a sufficient press fit on the shaft! This will ensure that both inner ring and shaft act as a unit - and both rotate at the same speed. It is also desirable to use a locknut to clamp the inner ring against the shaft shoulder.

If the applied load is of a rotating nature, for example - vibrating screens where unbalanced weights are

attached to the shaft, then the outer ring becomes the critical member. In order to eliminate creeping in this case, the outer ring must be mounted with a press fit in the housing. The rotating inner ring, when subjected to a rotating load, can be mounted with a slip fit on the shaft.

It is evident, therefore, that when the applied load is stationary with respect to the outer ring, a tight shaft fit is required. When the applied load is stationary with respect to the inner ring, a tight housing fit is required.

Some bearings may be pressed on the shaft by means of a brass tube. Pressure is applied to the inner ring of the bearing by the tubing. The assembly of larger bearings can be simplified by a "heating" procedure. Heat the bearing in clean oil to a temperature of approximately 90°C provided it is not prepacked and sealed. Care should be exercised not to exceed this temperature. Sufficient time should be allowed to assure that the bearing is heated throughout. This will sufficiently expand the bearing and permit it to slide easily over the shaft to its proper location. Care should be taken to prevent cocking of the inner ring as this may cause it to seize before the bearing is properly located. If this happens, it is best to remove the bearing promptly and reheat. When the bearing cools, it will shrink and grip the shaft. It requires only a little ingenuity to provide the tools to facilitate this procedure.

Shaft and Housing Fits

A ball or roller bearing has extremely accurate component parts which fit together with very close tolerance. The inner ring bore and the outer ring outside diameter must be manufactured within close limits to fit their respective supporting members - the shaft and the housing. It follows that the shaft and housing must also be machined to close limits. Only then, will we obtain the required fit when the bearing is mounted.

It is advisable to refer to the tables of shaft and housing fits as published in the bearing manufacturer's calalogue. These tables list recommended dimensions and tolerances for various operating conditions.

Adapter Sleeve

The use of a tapered adapter sleeve on standard shafting will greatly simplify the mounting of the bearing. The outer surface of the sleeve is tapered to match the tapered bore of the bearing inner ring. This will provide the required tight fit between the inner ring and the shaft. The adapter sleeve is slotted to permit easy contraction and is threaded at the small end to fit a locknut. When the sleeve is drawn-up tight between the bearing and the shaft, a press fit is provided both at the shaft and the inner ring.

A lockwasher between the inner ring and the locknut prevents the nut from loosening. The use of micronized graphite will greatly facilitate assembly - and help prevent contact erosion of the parts. A light coating of graphite is applied on the shaft, adapter sleeve and the bore of the inner ring. It is good practice to apply a coat of oil to the shaft, housing and component parts before the bearing unit is assembled.

Internal Bearing Fits

It is evident that a press fit between the parts will stretch the inner ring. This holds true when mounting the bearing directly on the shaft or by means of an adapter sleeve. Thus, there will be a tendency to reduce the initial internal radial clearance in the bearing.

If an excessive press fit is used, it is possible to reduce the bearing clearance sufficiently to make the bearing tight.

However, if the recommended shaft fits are used and normal operating temperatures prevail, the internal clearance remaining after mounting the bearing will be sufficient to ensure proper operation.

When an adapter mounting is used, some additional cautions should be heeded. If these are taken into consideration, the bearing will not be tight internally.

The following is recommended practice for mounting ball bearings on adapters. Slowly rotate and swivel the outer race by hand while tightening the locknut. A light drag in the bearing will be apparent as the inner ring stretches and the clearance is reduced. This is the point where further tightening of the nut is not desired. The nut should then be drawn up so that a prong of the lockwasher is opposite a slot in the nut.

Before mounting spherical roller bearings on adapters, the internal clearance should be checked and recorded. Insert a feeler gauge between the top roller and the outer ring. The bearing should be resting upright on a table when making this check.

After mounting the bearing on the shaft and adapter sleeve, the locknut is tightened sufficiently to reduce the initial clearance by the required amount. This is checked in the same manner as described, by using the feeler gauge. The decrease in internal clearance after mounting is found in the manufacturer's specifications as well as in the pillow block mounting instruction enclosure.

Temperature Conditions

Certain types of bearing applications require the consideration of variable temperature conditions.

For example: An induced draft fan handling gases at high temperature. The fan wheel is mounted on the shaft. Therefore, that part of the shaft in the fan casing is subjected to the high temperatures. The bearings are usually mounted directly outside the fan casing. Thus, the temperature of the shaft at the bearing location is considerably higher than the room temperature. It follows that the inner ring of the bearing (mounted on the shaft) will be considerably hotter than the outer ring. This is true, as the outer ring is mounted in the housing which is isolated from the fan and not subjected to the high temperature. As a result, the inner ring will expand more than the outer ring. This action reduces the internal clearance in the bearing - in addition to the reduction due to the tight fit on the shaft.

To compensate for this additional reduction of internal clearance in the bearing, some provision must be made. Bearings with an internal clearance greater than standard should be used. This additional clearance will compensate for internal clearance reduction due to the temperature differential between the inner and outer rings. There are other cases where bearings with internal clearance greater than standard are required. Amoung these are dryer cylinder bearings in paper machinery where steam passes through the hollow shaft - shaker screens where tight shaft and housing fits are required - high speed applications where the temperature rise in the bearing, due to speed and load, is abnormal.

If this additional internal clearance is not provided, the bearing will be excessively tight internally and cannot operate successfully. Excessive high operating temperatures and subsequent break-down of the lubricant due to carbonization will occur.

Free and Held Bearings

A temperature variation will expand or contract the component parts of any machine. Due to this condition, it is essential that such parts be permitted to expand or contract without restriction. For that reason, only one bearing on any one shaft should be fixed axially in the housing (called a "held" bearing) to prevent axial or end motion.

All other bearings on that same shaft should have adequate axial clearance in the housing (referred to as "free" bearings). Such free bearings will permit the shaft to elongate and contract without restriction.

Generally, it is preferred to hold the bearing at the drive end. However, consideration should be given to the bearing load. In some cases, it is best to hold the bearing that carries the smaller radial load, especially where the "held" bearing is subjected to a thrust load of some magnitude. This will tend to equalize the distribution of the load on the bearings.

In gear reducers where herringbone gears are used, only one bearing on one of the shafts should be "held", usually the input shaft. It is evident that the "V" shape of the gear teeth will locate the other shaft axially.

When a flexible coupling is used to connect two shafts, a "held" bearing is required on each of the shafts - as a flexible coupling permits end motion of both shafts.

Lubrication

The bearing unit can usually be lubricated with a good grade of sodium base grease for normal loads, speeds and operating conditions. The bearing housing should be filled approximately one-third full with grease.

An excessive quantity of grease will "build up" internal pressure in the bearing housing and result in high temperatures - and subsequent damage to the bearing.

Here is a safety measure to combat this danger when adding lubricant to the bearing. After the lubricant is added, remove the plug (preferably at the lower half of the housing) while the bearing is in operation. This permits the excessive lubricant to flow out of the housing and relieve the internal pressure. When the flow of grease ceases, be sure to replace the plug.

Speed and other operating conditions, in some cases, require that oil lubrication be used. In that event, the bearing housing should be equipped with adequate oil fittings. Such fittings should provide a static oil level at the centre of the lowest ball or roller in the bearing.

Either pipe fittings, commercial oil cups or glass gauges can be used. However, it is preferable to use sight glass oil gauges which can be clearly marked for static and operating levels. The operating level is slightly lower than the static level due to agitation of the oil.

The static level can be marked on the gauge before the unit is assembled. The operating level can be determined only after the bearing is in operation. The gauge should also be marked for the operating level and the lubricant, at no time, should be permitted to drop below this point.

Do's and Don'ts on Lubrication

Follow instructions when furnished with machinery. Use only grease where grease is specified and oil where oil is specified. Be sure to use exactly the kind of lubricant the instructions call for.

Store grease in clean containers. Handle grease with clean paddles or grease guns. Keep grease containers covered.

Don't overfill. Grease or oil will ooze out of overfilled housings past seals and closures, collect dirt and cause trouble. Too much lubricant will also cause overheating. This is particularly true of bearings running at high speeds where the churning of the lubricant will cause the bearings to run excessively hot.

Don't permit any machine to stand around for months without turning it over once in a while so that all surfaces of the bearings will be covered with lubricant. Oil tends to drain down off a standing bearing and moisture may condense in the housing and cause corrosion.

Inspect seals and vents regularly.

BEARING FAILURES AND THEIR CAUSES

Just as a doctor cannot effect a lasting cure unless he knows the cause of an illness, the maintenance person must know the reasons for a bearing failure before he can correct such a condition.

While ball and roller bearings have proved by long experience to be much more reliable and to need less attention than bearings of other types, the principles governing their use are necessarily quite different from those applicable to plain bearings. Therefore, it is of utmost importance to draw the right inference from bearing failures.

Sometimes, this can be done very quickly by a casual inspection of the bearing and the condition surrounding the application. Other times, it is necessary to make a complete laboratory examination before the cause can be

determined. In addition, there are times when the condition of the filed bearing is such that the actual cause of failure cannot be definitely established and an exhaustive study of the application and all conditions surrounding it must be made.

1. Dirt and Other Foreign Matter

One of the common causes of bearing failure is dirt. Bearings which fail because of dirt can be recognized in several ways. Generally, fine dirt in a bearing acts as an abrasive and causes lapping of the bearing parts. This can be seen and felt in the ball or roller paths of the self-aligning type bearing. These paths will be polished as will the balls and rollers. If there are no breaks in the surfaces of the rolling elements and the ball or roller path is clearly defined, then you can be sure that fine dirt was in it during service.

Bearings of the deep-groove type are not as easily examined since the ball paths and the balls cannot be readily seen. A preliminary check can be made by feeling the amount of clearance between the inner and outer races. This can be done by laying the bearing on a flat surface and holding one ring stationary. If the other ring can be moved in a position parallel to the flat surface, wear has taken place. Do not attempt to feel wear in a bearing when holding it in your hands. In this position, it is possible to feel the normal internal clearance which might be mistaken for wear.

Ball and roller bearings do not wear, even after long service, if they are kept clean and are lubricated properly. When they have reached their fatigue-limit, flaking of the loaded areas occurs. This flaking is not considered

wear in the same sense that we consider wear caused by abrasives. Many worn bearings have to be discarded long before the fatigue limit of the steel is reached.

If water or other corrosive agents enter the bearing, wear will occur very quickly. The iron oxide formed by rust is an abrasive and will lap or grind the balls or rollers undersize. Sometimes a bearing will become corroded before it is put in service. A motor or pump or some other machine may be flooded or water may be introduced with the lubricant. In a case of this kind, corrosion pitting will occur and is distinguished by its dark brown color. This pitting will be where the balls or rollers contact the races. It will cause the bearing to be noisy and since the machine has just been put into service, the user will immediately blame the bearing.

If examination of a bearing indicates that wear has taken place, the actual application should be carefully checked. You may find a quantity of hard, gritty particles, such as produced by a grinding wheel or a buffing stand. Seals should be checked thoroughly to make sure that dirt is not going past the seals and into the bearing. The lubricant should be checked as well as the method of lubricating the bearings. Slipshod maintenance methods could be the reason for dirt getting into the lubricant and then passed on into the bearing.

Sometimes a simple, inexpensive shroud or sheet metal box can be used to deflect the dirt away from the bearing housing. This will pay for itself many times over.

The same conditions are obtained as a result of water or other corrosive agents entering the bearing housing. Everything possible should be done to deflect such fluids away from the openings of the bearing housing.

Foreign matter may get into the bearing in the form of chips or particles of steel because of failure of another part of the machine - such as a gear. Such chips in the ball path will be pressed into the races and balls or rollers, causing dents or scratches.

2. Inadequate or Improper Lubrication

A common cause of early bearing failure is insufficient lubrication. The amount of lubricant required by a ball or roller bearing is small. That is why so many of these bearings, unlike the majority of plain bearings, can be lubricated with grease. While the amount required may be small, the quality should be the best obtainable.

Some applications involving high temperatures, high speeds, very heavy loads, etc., require oil lubrication. In some instances, special methods are used for oil lubrication, such as "circulating oil", "oil mist", "drop feed", etc.

Lack of lubricant is revealed by a high pitched sound and a rapid rise in temperature. (A rise in temperature can also be the sign of over-lubrication.) Failure to correct this fault immediately is apt to be followed by damage. Intense overheating will draw the temper of the bearing steel, the parts will become soft and the bearing will fail very quickly. This condition can quickly be recognized by the colour of the bearing which in the early

stages will be blue. If the bearing is forced to continue to operate, it might seize and result in damage to other parts.

Lack of lubricant may cause wear of the cage accompanied by smearing of the balls or rollers and their tracks in the rings.

Grease whose consistency is too solid, or oil that is too thick, is capable of producing a braking effect powerful enough to make the rolling elements slide. Such sliding will cause smearing of the effected parts and early failure occurs.

Very rapid starting of a machine is an adverse condition for a rolling bearing. Where the load is heavy, a condition such as the one described in the foregoing paragraph occurs. This smearing takes place because of the sliding of the parts before the running temperature has been reached and while the grease is still solid. This is particularly true where bearings operate under low temperature conditions. Where the load is light, the inner race slides or skids on the balls or rollers before they have a chance to rotate and smearing again takes place. Under both conditions, the bearing will continue to operate but will become noisy and eventually will fail.

3. Incorrect Machining of Shafts and Housings

If the specified shaft diameter is exceeded, or the housing bore undersize, the internal radial clearance of the bearing may be removed due to the expansion of the inner ring and contraction of the outer ring.

Both of these conditions will cause an overload of the bearing, and flaking (it is sometimes known as spalling) of the races or balls takes

place. This condition may be recognized by the appearance of the parts under load--their surfaces are chipped and flaked. It differs from wear since it is rough, rather than smooth. This is the normal way for a bearing to fail after long service under load. If it takes place in a short period of time then the bearing has been overloaded by some outside cause.

Normal fatigue failures generally show a load track around the circumference of one ring and over one section of the other. Should the load track appear at two or more places in the one race, then internal loading is the cause.

For example, if the bore of the housing is out of round or undersize, the outer race will be squeezed out of shape, causing overload. In a cartridge mounting, the housing bore may be correct when disassembled but if the cartridge is put into a machine frame which is bored undersize, it may be squeezed out of round.

Distortion of the housing bore may occur if the pedestal on which the pillow block is bolted is not straight or smooth. The dimension of the housing may be correct, yet it is possible to pinch a bearing in a split housing if the bearing is not seated squarely in the bearing seat. If the cap is bolted down with the bearing in this position, pinching will take place across the diagonal corners of the outer ring.

The loading of bearings which are pinched in their housings because of cocking is very evident upon examination. A definitely defined load track will be noticeable on opposite sides of the outer race across the same diagonal where the pinching occurred.

Bearings mounted on a tapered shaft or on a tapered adapter sleeve can be overloaded at the time of mounting. If the inner race is forced up on the taper too far, it will expand excessively and the normal internal radial looseness in the bearing will be removed. When mounting ball bearings of this type, care should be exercised to rotate the outer race when the bearing is forced up on the taper. When it starts to bind to the smallest degree, the inner race has expanded as much as it should. In a spherical roller bearing, both the amount of initial internal radial clearance and the necessary expansion of the inner ring, when mounted on a tapered shaft or sleeve, are such that the decrease in internal clearance can be measured with a feeler gauge. Thus, you can be sure the reduction is in accordance with specifications given in catalogues.

Extreme care must always be exercised to ensure proper shaft and housing fits. Undersized shafts and oversized housing bores will also cause early bearing failures. An undersized shaft will permit the inner ring to rotate on the shaft--while an oversized housing bore will permit the outer ring to spin in the housing. Both conditions will cause heat, smearing of the parts that rub, and rubbing cracks--all of which may lead to early failure.

4. Incorrect Mounting and Abuse

Misalignment of either race of a deep groove bearing will impose an undetermined load on the bearing. This load, together with the normal load on the bearing, will cause an overload resulting in early failure.

Misalignment also imposes undue stress on the retainer. In fact, this condition and poor lubrication are the main causes for retainer failures. If misalignment is present, it will be indicated by a ball track not parallel to the edge of the groove. When the misaligned path is in the outer race (in applications where the inner race rotates) then the bore of the housing is not parallel to the shaft. If the load path in the inner ring is not parallel with the edge of the groove, it is generally due to the inner ring being cocked on the shaft, the shaft shoulder not square with the bearing seat, or the shaft being bent.

Sometimes a condition like this can develop in the case of a cartridge housing mounting. The bearing may be mounted perfectly in the cartridge but if this unit is not bolted squarely to the machine frame, misalignment may result.

Another cause of initial overloading is an opposed mounting which binds the outer race and causes excessive thrust. Most mounting designs require that one bearing be held within its housing shoulders while all other bearings on that same shaft are allowed to be free to float in the housing. However, there are mounting designs which require that the outer races of two bearings be opposed, i.e. opposite sides of the two bearings are mounted against the shoulder of each housing. The spacing between these housing shoulders must be quite accurate in relation to the distance between the bearing shoulders on the shaft. Otherwise, excessive initial end thrust will be imposed on the bearing.

Pitting due to electric action causes noisy bearing operation. This occurs in electric motors and generators when electric current passes through the bearing from the frame to the shaft. An actual

crater is burned in the steel by the arcing of the electric current. When the condition is very bad, these craters can be seen with the naked eye. Smaller ones require high magnification.

Bearings can become ball dented and when operated in this condition will be very noisy. Ball denting or brinelling is caused by excessive pressure on the races through the balls when the bearing is not rotating. It commonly occurs in small bearings that are mounted in the housing while the inner race is on the shaft. If the outer race is tight or becomes cocked in the housing and pressure to force it into position is applied through the inner race, such impressions are produced.

When the impact is in an axial direction, the balls can be forced against the edge of the groove which in turn, nicks them. Ball dents are easily distinguished from dents produced by chips or dirt because they are usually spaced the same distance apart as the position of the balls. Ball dents can be produced in the bottom of a groove if sufficient impact goes through the balls in a radial direction. If a motor is dropped from a shelf to the floor and the overhanging end of the shaft strikes first, then denting of this nature can take place.

Another condition similar to ball denting is known as pocketing or false brinelling. In this condition, the pockets are also spaced the same distance apart as are the balls or rollers and because of this, it is often confused with denting. The cause, however, is entirely different and is due to vibration while the bearing is not rotating. If a shaft is supported by the bearings in transit and the parts are not bound tightly together, small pockets can be produced in the tracks. Such false

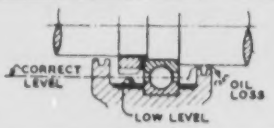
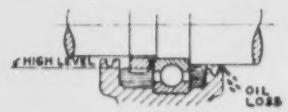
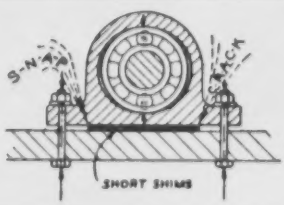
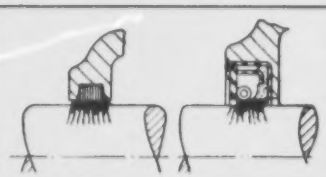
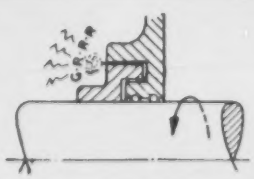
brinelling is also likely to take place if two separate units are mounted on a common base and only one is operated at a time. The vibration caused by running one unit will cause the balls or rollers of the other, which is not running, to jiggle against the races and produce these small pockets. They can easily be distinguished from ball dents, especially if the race is examined with a magnifying glass, as the polishing lines in the race have been worn away at each pocket. On the other hand, ball dents depress the surface (deform it), and the polishing lines will continue on through these depressions.

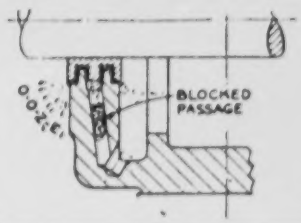
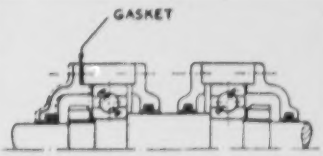
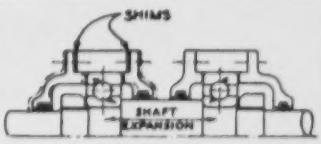
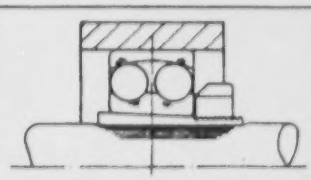
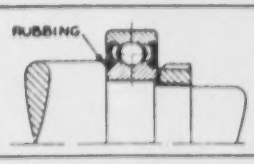
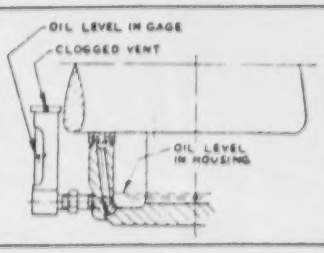
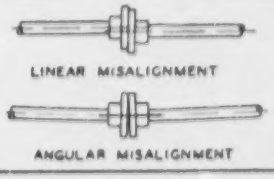
A common claim on the part of a customer is that a bearing has a flat ball. When such bearings are examined, it is found that the noisy condition which the customer thought was caused by a flat ball is due to something entirely different. It is extremely rare that defects in material or hardening are the cause of early bearing failure or noisy bearings. Another common complaint is a cracked inner race of small bearings. In most instances, it will be found that the shaft is oversize and the inner race was expanded excessively. It is possible that the inner race may have been forced on the shaft while it was in a cocked position.

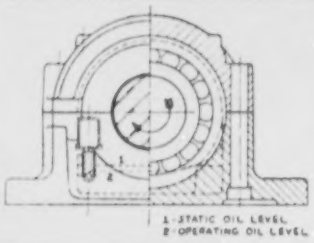
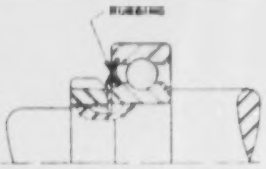
Bearings, though in common use every day, are precision units. They must be treated with common-sense care if they are to perform as expected.

TROUBLESHOOTING

OVERHEATED BEARING

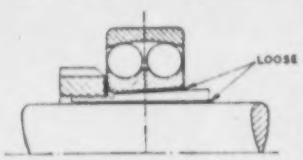
	REASON FOR CONDITION	PRACTICAL SOLUTION	
1	Wrong type of grease or oil causing break-down of lubricant.	Consult reliable lubricant manufacturer for proper type of lubricant. Check manufacturer's instructions to determine if oil or grease should be used.	
2	Low oil level. Loss of lubricant through seal. Insufficient grease in housing.	Oil level should be at center of lowest ball or roller in bearing. Using grease, lower half of pillow block should be filled.	
3	Housing packed with grease, or oil level too high . . . causing excessive churning of lubricant, high operating temperature, oil leakage.	Purge bearing until only lower half of housing is filled with grease. Using oil lubrication, reduce level to center of lowest ball.	
4	Bearings selected with inadequate internal clearance for conditions where external heat is conducted thru shaft, thereby expanding excessively the inner ring.	Replacement bearing should have identical marking as original bearing for proper internal clearance.	
5	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	Check and scrape housing bore to relieve pinching of bearing. Be sure pedestal surface is flat, and shims cover entire area of pillow block base.	
6	Felt too tightly packed in felt groove. Leather or composition seals with excessive spring tension or dried out.	Stretch felt to reduce friction. Replace leather or composition seals with ones having reduced spring tension. Lubricate seals.	
7	Rotating seals rubbing against stationary parts.	Check running clearance of rotating seal to eliminate rubbing. Correct alignment.	

	REASON FOR CONDITION	PRACTICAL SOLUTION	
8	Oil return holes blocked—pumping action of seals cause oil leakage.	Clean holes. Drain out used oil—refilling to proper oil level with fresh lubricant.	
9	Opposed mounting.	Insert gasket between housing and cover flange to relieve axial preloading of bearing.	
10	Two "held" bearings on one shaft. Excessive shaft expansion.	Back off covers in one of the housings, using shims to obtain adequate clearance of outer ring, to permit free axial bearing motion.	
11	Adapter tightened excessively.	Loosen locknut and sleeve assembly. Retighten sufficiently to clamp sleeve on shaft but be sure bearing turns freely.	
12	Unbalanced load. Housing bore too large.	Rebalance machine. Replace housing with one having proper bore.	
13	Rubbing of shaft shoulder against bearing seals.	Remachine shaft shoulder to clear seal.	
14	Incorrect oil level. Result: no lubricant in bearing.	Clean out clogged hole to vent oil gauge.	
15	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	Correct alignment by shimming pillow blocks. Be sure shafts are coupled in straight line—especially when three or more bearings operate on one shaft.	

	REASON FOR CONDITION	PRACTICAL SOLUTION	
16	Incorrect mounting of constant oil level cup. (Too high or too low.) Cup located opposite rotation of bearing permitting excessive flow of oil, resulting in too high oil level.	Oil level should be at center of lowest ball or roller when operating. Locate cup with rotation of bearing. Sketch illustrates correct position of constant level oil cup with respect to rotation.	
17	Prong rubbing against bearing.	Remove lockwasher — straighten prong or replace with new washer.	
18	Bearing seat diameter machined oversize, causing excessive expansion of shaft and bearing inner ring, thus reducing clearance in bearing.	Grind shaft to get proper fit between inner ring of bearing and shaft.	
19	"Pounding-out" of housing bore due to soft metal. Result: enlarged bore . . . causing spinning of outer ring in housing.	Rebore housing and press steel bushing in bore. Machine bore of bushing to correct size. If loads are not excessive, tighter fit in housing, without the use of the steel bushing, may correct the trouble.	

NOISY BEARING

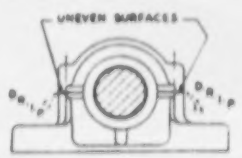
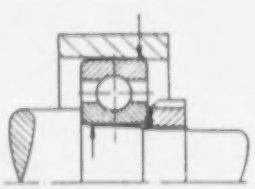
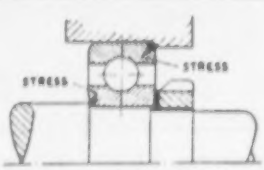
1	Wrong type of grease or oil causing break-down of lubricant.	See Item 1 - Overheated Bearing
2	Low oil level. Loss of lubricant through seal. Insufficient grease in housing.	See Item 1 - Overheated Bearing
3	Bearings selected with inadequate internal clearance for conditions where external heat is conducted thru shaft, thereby expanding excessively the inner ring.	See Item 1 - Overheated Bearing
4	Foreign matter (dirt, sand, carbon, etc.) entering bearing housing.	Clean out bearing housing. Replace worn-out seals or improve seal design to obtain adequate protection of bearing.
5	Corrosive agents (water, acids, paints, etc.) entering the bearing housing.	Addition of a shroud and (or) flinger to throw off foreign matter.
6	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	See Item 5 - Overheated Bearing

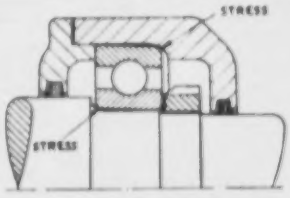
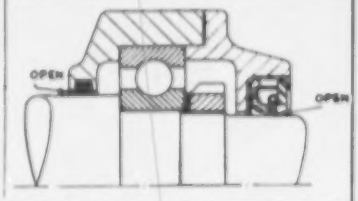
	REASON FOR CONDITION	PRACTICAL SOLUTION
7	Failure to remove chips, dirt, etc. from bearing housing before assembling bearing unit.	Carefully clean housing, and use fresh lubricant.
8	Rotating seals rubbing against stationary parts.	See Item 7 - Overheated Bearing
9	Opposed mounting.	See Item 9 - Overheated Bearing
10	Two "held" bearings on one shaft. Excessive shaft expansion.	See Item 10 - Overheated Bearing
11	Shaft diameter too small. Adapter not tightened sufficiently.	Metallize shaft and regrind to obtain proper fit. Retighten adapter to get firm grip on shaft. 
12	Adapter tightened excessively.	See Item 11 - Overheated Bearing
13	Flat on ball or roller due to skidding. (Result of fast starting.)	Carefully examine balls or rollers, looking for flat spots on the surface. Replace bearing.
14	Rubbing of shaft shoulder against bearing seals.	See Item 13 - Overheated Bearing
15	Distortion of bearing seals.	Remachine housing shoulder to clear seal.
16	Prong rubbing against bearing.	See Item 17 - Overheated Bearing
17	Incorrect method of mounting. Hammer blows on bearing.	Replace with new bearing. Don't hammer any part of bearing when mounting.
18	Interference of other movable parts of machine.	Carefully check every moving part for interference. Reset parts to provide necessary clearance.
19	Distorted shaft and other parts of bearing assembly.	Only in extreme cases should a blow torch be used to facilitate removal of a failed bearing. Care should be exercised to avoid high heat concentration at any one point so distortion is eliminated.

	REASON FOR CONDITION	PRACTICAL SOLUTION
20	Bearing seat diameter machined oversize causing excessive expansion of shaft and bearing inner ring, thus reducing clearance in bearing.	Grind shaft to get proper fit between inner ring of bearing and shaft.
21	Unbalanced load. Housing bore too large.	Rebalance unit. Replace housing with one having proper bore.
22	"Pounding-out" of housing bore due to soft metal. Result: enlarged bore . . . causing spinning of outer ring in housing.	Rebore housing and press steel bushing in bore. Machine bore of bushing to correct size. If loads are not excessive, tighter fit in housing, without the use of the steel bushing, may correct the trouble.
23	Bearing exposed to vibration while machine is idle.	Carefully examine bearing for wear spots separated by distance equal to the spacing of the balls. Replace bearing.

REPLACEMENTS ARE TOO FREQUENT

1	Wrong type of grease or oil causing break-down of lubricant.	See Item 1 - Overheated Bearing
2	Low oil level. Loss of lubricant through seal. Insufficient grease in housing.	See Item 2 - Overheated Bearing
3	Bearings selected with inadequate internal clearance for conditions where external heat is conducted thru shaft, thereby expanding excessively the inner ring.	See Item 3 - Overheated Bearing
4	Foreign matter (dirt, sand, carbon, etc.) entering into bearing housing.	Clean out bearing housing. Replace worn-out seals or improve seal design to obtain adequate protection of bearing.
5	Corrosive agents (water, acids, paints, etc.) entering the bearing housing.	Addition of a shroud and (or) flinger to throw off the foreign matter.
6	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	See Item 5 - Overheated Bearing
7	Failure to remove chips, dirt, etc. from bearing housing before assembling bearing unit.	Carefully clean housing, and use fresh lubricant.

	REASON FOR CONDITION	PRACTICAL SOLUTION
8	Oil leakage resulting from air flow over bearings. (Example: forced draft fan with air inlet over bearings.)	Provide proper baffles to divert direction of air flow.
9	Opposed mounting.	See Item 9 - Overheated Bearing
10	Two "held" bearings on one shaft. Excessive shaft expansion.	See Item 10 - Overheated Bearing
11	Shaft diameter too small. Adapter insufficiently tightened.	See Item 11 - Noisy Bearing
12	Adapter tightened excessively.	See Item 11 - Overheated Bearing
13	Oil leakage at housing split. Excessive loss of lubricant.	If not severe, use thin layer of gasket cement. Don't use shims. Replace housing if necessary. 
14	Unbalanced load. Housing bore too large.	See Item 12 - Overheated Bearing
15	Unequal load distribution on bearing.	Rework shaft, housing, or both, to obtain proper fit. May require new shaft and housing. 
16	Inadequate shoulder support causing bending of shaft.	Remachine shaft fillet to relieve stress. May require shoulder collar. 
17	Inadequate support in housing causing cocking of outer ring.	Remachine housing fillet to relieve stress. May require shoulder collar.
18	Rubbing of shaft shoulder against bearing seals.	See Item 13 - Overheated Bearing
19	Distortion of bearing seals.	See Item 15 - Noisy Bearing

	REASON FOR CONDITION	PRACTICAL SOLUTION
20	Distortion of shaft and inner ring. Uneven expansion of bearing inner ring.	Remachine shaft fillet to obtain proper support. 
21	Distortion of outer housing and ring. Pinching of bearing.	Remachine housing fillet to obtain proper support.
22	Rotating seals rubbing against stationary parts.	See Item 7 - Overheated Bearing
23	Incorrect oil level. Result: no lubricant in bearing.	See Item 14 - Overheated Bearing
24	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	See Item 15 - Overheated Bearing
25	Incorrect mounting of constant oil level cup. (Too high or low.) Cup located opposite rotation of bearing.	See Item 16 - Overheated Bearing
26	Incorrect method of mounting. Hammer blows on bearing.	Replace with new bearing. Don't hammer any part of bearing when mounting.
27	Excessively worn felt, leather (or composition), or labyrinth seals. Result: lubricant loss; dirt getting into bearing.	Replace seals after thoroughly flushing bearing and refilling with fresh lubricant. 
28	Bearing seat diameter machined oversize, causing excessive expansion of shaft and bearing inner ring, thus reducing clearance in bearing.	Grind shaft to get proper fit between inner ring of bearing and shaft.
29	"Pounding-out" of housing bore due to soft metal. Result: enlarged bore . . . causing spinning of outer ring in housing.	Rebore housing and press steel bushing in bore. Machine bore of bushing to correct size. If loads are not excessive, tighter fit in housing, without the use of the steel bushing, may correct the trouble.

VIBRATION

1	Foreign matter (dirt, sand, carbon, etc.) entering bearing housing.	Clean out bearing housing. Replace worn-out seals or improve seal design to obtain adequate protection of bearing.

	REASON FOR CONDITION	PRACTICAL SOLUTION
2	Corrosive agents (water, acids, paints, etc.) entering the bearing housing.	Addition of a shroud and (or) flinger to throw off foreign matter.
3	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	See Item 5 - Overheated Bearing
4	Failure to remove chips, dirt, etc. from bearing housing before assembling bearing unit.	Carefully clean housing, and use fresh lubricant.
5	Shaft diameter too small. Adapter not tightened sufficiently.	See Item 11 - Noisy Bearing
6	Unbalanced load. Housing bore too large.	See Item 12 - Overheated Bearing
7	Flat on ball or roller due to skidding. (Result of fast starting.)	Carefully examine balls or rollers, looking for flat spots on the surface. Replace bearing.
8	Unequal load distribution on bearing.	See Item 15 - Replacements are too frequent
9	Inadequate shoulder support causing bending of shaft.	See Item 16 - Replacements are too Frequent
10	Inadequate support in housing causing cocking of outer ring.	See Item 17 - Replacements are too Frequent
11	Distortion of shaft and inner ring. Uneven expansion of bearing inner ring.	See Item 20 - Replacements are too Frequent
12	Distortion of outer housing and ring. Pinching of bearing.	See Item 21 - Replacements are too Frequent
13	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	See Item 15 - Overheated Bearing
14	Incorrect method of mounting. Hammer blows on bearing.	Replace with new bearing. Don't hammer any part of bearing when mounting.
15	Excessive clearance in bearing, resulting in vibration.	Use bearings with recommended internal clearances.
16	Vibration of machine.	Check balance of rotating parts. Rebalance machine.
17	"Pounding-out" of housing bore due to soft metal. Result: enlarged bore . . . causing spinning of outer ring in housing.	Rebore housing and press steel bushing in bore. Machine bore of bushing to correct size. If loads are not excessive, tighter fit in housing, without the use of the steel bushing, may correct the trouble.

UNSATISFACTORY PERFORMANCE OF EQUIPMENT

	REASON FOR CONDITION	PRACTICAL SOLUTION
1	Bearings selected with inadequate internal clearance for conditions where external heat is conducted thru shaft, thereby expanding excessively the inner ring.	See Item 4 - Overheated Bearing
2	Foreign matter (dirt, sand, carbon, etc.) entering bearing housing.	Clean out bearing housing. Replace worn-out seals or improve seal design to obtain adequate protection of bearing.
3	Corrosive agents (water, acids, paints, etc.) entering the bearing housing.	Addition of a shroud and (or) flinger to throw off foreign matter.
4	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	See Item 5 - Overheated Bearing
5	Failure to remove chips, dirt, etc. from bearing housing before assembling bearing unit.	Carefully clean housing, and use fresh lubricant.
6	Two "held" bearings on one shaft. Excessive shaft expansion.	See Item 10 - Overheated Bearing
7	Shaft diameter too small. Adapter not tightened sufficiently.	See Item 11 - Noisy Bearing
8	Adapter tightened excessively.	See Item 11 - Overheated Bearing
9	Unbalanced load. Housing bore too large.	See Item 12 - Overheated Bearing
10	Flat on ball or roller due to skidding. (Result of fast starting.)	Carefully examine balls or rollers, looking for flat spots on the surface. Replace bearing.
11	Unequal load distribution on bearing.	See Item 15 - Replacements are too Frequent
12	Inadequate shoulder support causing bending of shaft.	See Item 16 - Replacements are too Frequent
13	Inadequate support in housing causing cocking of outer ring.	See Item 17 - Replacements are too Frequent

	REASON FOR CONDITION	PRACTICAL SOLUTION
14	Distortion of shaft and inner ring. Uneven expansion of bearing inner ring.	See Item 20 - Replacements are too Frequent
15	Distortion of outer housing and ring. Pinching of bearing.	See Item 21 - Replacements are too Frequent
16	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	See Item 15 - Overheated Bearing
17	Prong rubbing against bearing.	See Item 17 - Overheated Bearing
18	Incorrect method of mounting. Hammer blows on bearing.	Replace with new bearing. Don't hammer any part of bearing when mounting.
19	Excessive clearance in bearing, resulting in vibration.	Use bearings with recommended internal clearances.
20	Vibration of machine.	Check balance of rotating parts. Rebalance machine.
21	Shaft and housing shoulders, and face of locknut out of square with bearing seat.	Remachine parts to obtain squareness.
22	"Pounding-out" of housing bore due to soft metal. Result: enlarged bore . . . causing spinning of outer ring in housing.	Rebore housing and press steel bushing in bore. Machine bore of bushing to correct size. If loads are not excessive, tighter fit in housing, without the use of the steel bushing, may correct the trouble.

BEARING IS LOOSE ON SHAFT

1	Shaft diameter too small. Adapter not tightened sufficiently.	See Item 11 - Noisy Bearing
2	Knurling and center punching of bearing seat on shaft.	Unsatisfactory because high spots are flattened when load is applied. When fit is loose, metallize shaft and reground to proper size.

HARD TURNING OF SHAFT

1	Wrong type of grease or oil causing break-down of lubricant.	See Item 1 - Overheated Bearing

	REASON FOR CONDITION	PRACTICAL SOLUTION
2	Low oil level. Loss of lubricant through seal. Insufficient grease in housing.	See Item 2 - Overheated Bearing
3	Housing packed with grease, or oil level too high . . . causing excessive churning of lubricant, high operating temperature, oil leakage.	See Item 3 - Overheated Bearing
4	Bearings selected with inadequate internal clearance for conditions where external heat is conducted thru shaft, thereby expanding excessively the inner ring.	See Item 4 - Overheated Bearing
5	Foreign matter (dirt, sand, carbon, etc.) entering bearing housing.	Clean out bearing housing. Replace worn-out seals or improve seal design to obtain adequate protection of bearing.
6	Corrosive agents (water, acids, paints, etc.) entering the bearing housing.	Addition of a shroud and (or) flinger to throw off foreign matter.
7	Housing bore out of round. Housing warped. Excessive distortion of housing. Undersized housing bore.	See Item 5 - Overheated Bearing
8	Failure to remove chips, dirt, etc. from bearing housing before assembling bearing unit.	Carefully clean housing, and use fresh lubricant.
9	Felt too tightly packed in felt groove. Leather or composition seals with excessive spring tension or dried out.	See Item 6 - Overheated Bearing
10	Rotating seals rubbing against stationary parts.	See Item 7 - Overheated Bearing
11	Opposed mounting.	See Item 9 - Overheated Bearing
12	Two "held" bearings on one shaft. Excessive shaft expansion.	See Item 10 - Overheated Bearing
13	Adapter tightened excessively.	See Item 11 - Overheated Bearing

	REASON FOR CONDITION	PRACTICAL SOLUTION
14	Inadequate shoulder support causing bending of shaft.	See Item 16 - Replacements are too Frequent
15	Inadequate support in housing causing cocking of outer ring.	See Item 17 - Replacements are too Frequent
16	Distortion of bearing seals.	See Item 15 - Replacements are too Frequent
17	Distortion of shaft and inner ring. Uneven expansion of bearing inner ring.	See Item 20 - Replacements are too Frequent
18	Distortion of outer housing and ring. Pinching of bearing.	See Item 21 - Replacements are too Frequent
19	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	See Item 15 - Overheated Bearing
20	Shaft and housing shoulders, and face of locknut out of square with bearing seat.	Remachine parts to obtain squareness.
21	Bearing seat diameter machined oversize, causing excessive expansion of shaft and bearing inner ring, thus reducing clearance in bearing.	Grind shaft to get proper fit between inner ring of bearing and shaft.

SUBJECT: PREVENTIVE MAINTENANCE

TOPIC: 6 ALIGNMENT

OBJECTIVES:

The trainee will be able to:

1. Recall the problems resulting from faulty alignment.
2. Recall and explain the two types of misalignment.
3. Describe how to conduct:
   a) an angular alignment check
   b) a parallel alignment check.
4. Recall the factors that may disturb alignment.

ALIGNMENT

All mechanical equipment where a driving element is involved must be correctly aligned on the job prior to being put into service. This topic will deal only with shaft or coupling alignment. Misalignment can also occur on other units such as those that are belt or chain driven, however correction is much less complex.

Problems resulting from faulty alignment include:

1. noisy operation
2. reduced bearing life
3. excessive coupling wear
4. waste of power.

FOUNDATION

To ensure a long-lasting alignment of any unit, the foundation should be sufficiently substantial to absorb any vibration and to form a permanent, rigid support for the base plate. This is important in maintaining the alignment of a direct connected unit. A concrete foundation on a solid base should be satisfactory. Foundation bolts of the proper size should be embedded in the concrete, located by a drawing or template. A pipe sleeve about two and one-half diameters larger than the bolt should be used to allow movement for the final positioning of the bolts.

Factory Alignment

Pumps and drivers that are received from the factory with both machines mounted on a common baseplate, were accurately aligned before shipment. All baseplates are flexible to some extent and, therefore, must not be relied upon to maintain the factory alignment. Preliminary alignment is necessary after the complete unit has been

leveled on the foundation and again, after the unit is piped, and rechecked periodically as outlined in the following paragraphs.

Field Alignment

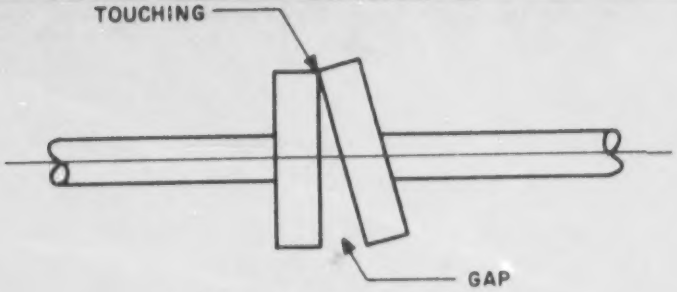
The faces of the coupling halves should be spaced far enough apart so that they cannot strike each other when the driver rotor is moved toward the pump. The necessary tools for checking the alignment of a flexible coupling are a straight edge and a taper gauge or a set of feeler gauges. *In cases where extreme accuracy is necessary, a dial indicator may be used to align the coupling.*

SHAFT ALIGNMENT

It should be emphasized that when shaft alignment is spoken of, that it is shafts and not the couplings which are the subject of discussion. The purpose of the flexible coupling is to compensate for temperature changes and to permit end movement of the shafts without interference with each other while transmitting power from the driver to the pump.

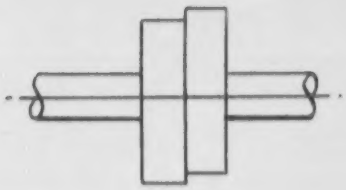
A flexible coupling should not be used to compensate for misalignment of a pump and driver shafts.

Consider, for example, a rigid coupling joining a driven and a driving shaft where the bore of one of the halves of the coupling is not square with the face. Even with the shafts in line, when the half couplings are brought together for bolting, it will be found that whereas at one point the engaging faces touch, at another point a space will exist between these faces, as shown in Figures 6 1(a) and 6 - 1(b). These two illustrations have been greatly exaggerated for purposes of demonstration.



EFFECT OF COUPLING BORE NOT SQUARE WITH COUPLING FACE.

Figure 6-1(a)



EFFECT OF COUPLING NOT CONCENTRIC WITH SHAFT

Figure 6-1(b)

If under these conditions, the coupling halves are forcibly drawn together by the coupling bolts, the shafts will be forced to take a bowed shape to compensate for the error in the machining of the coupling. Large stresses will be set up in the parts and a pronounced tendency to vibration will be introduced. A situation such as this may be corrected by machining the coupling half on a lathe, so that the coupling face is perpendicular to the shaft axis.

Thus, it will be seen that in order to effect correct shaft alignment the coupling halves (which are used for aligning the shafts) must have true coupling faces. Generally, the couplings should be checked for trueness of coupling face (square to shaft and flat) and periphery (round and concentric) to the shaft. *As a rule the couplings will have been accurately machined and this will not be a problem in alignment. However the installation man should be aware of such a possibility.*

The faces of the coupling halves should be spaced far enough apart so that they cannot strike each other when the driver rotor is moved hard over toward the pump. Due allowance should be made for wear of the thrust bearings. A minimum dimension for the separation of the coupling halves is usually specified by the manufacturer. The necessary tools for approximately checking the alignment of a flexible coupling are a straight edge and a taper gauge or a set of feeler gauges.

Types of Misalignment

There are two types of misalignment, although usually it is a combination of both. Shown in Figure 6-2, and 6-3 these are:

1. Parallel or offset misalignment: the shaft axes are parallel but not collinear.

2. Angular misalignment: the shaft axes intersect but are not collinear.

Parallel alignment check is made by placing a straight edge across both coupling rims at the top, bottom and at both sides. The unit will be in parallel alignment when the straight edge rests evenly on the coupling rim at all positions. Allowance may be necessary for temperature changes and for coupling halves that are not of the same outside diameter. Care must be taken to have the straight edge parallel to the axis of the shafts. (See Figure 6-2).

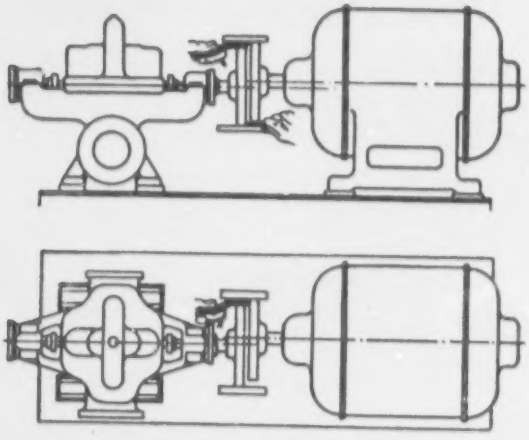


Figure 6-2 Parallel Misalignment

Angular alignment check is made by inserting the taper gauge or feelers between the coupling faces at 90 degree intervals around the coupling. The unit will be in angular alignment when the coupling faces are exactly the same distance apart at all points. (See Figure 6-3).

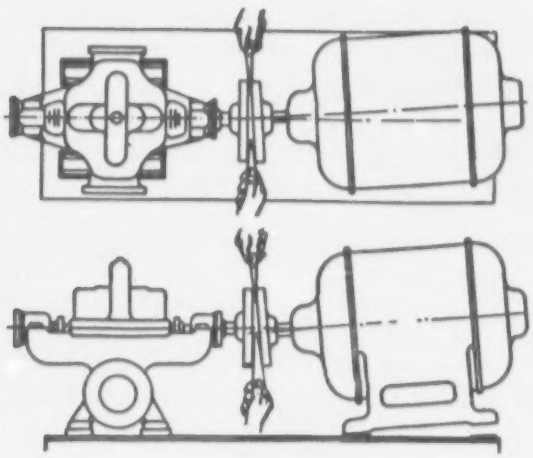


Figure 6-3 Angular Misalignment

Correction for Angular and Parallel Misalignment is made by adjusting the wedges or shims under the base-plate unless pump or motor is mounted in the field. Then after each change, it is necessary to recheck the alignment of the coupling halves. Adjustment in one direction may disturb adjustments already made in another direction.

The permissible amount of coupling misalignment will vary with the type of pump and driver, but in all cases conform to the coupling manufacturer's specifications.

When the preliminary alignment has been completed tighten the foundation bolts and recheck shaft alignment.

If the unit, i.e. pump is to be connected to the prime mover by gears or chains, the alignment should be checked by a straight edge across the faces of the gears or sprockets. This should be done in two directions at an angle as large as permitted by the relative size of the gears or sprockets. When pumps or prime movers will be heated in operation, i.e. pumps handling hot liquids, the unit should be aligned under the thermal conditions so that contraction and expansion due to temperature changes may be taken into account.

Alternate Method of Alignment

An approved method for putting the coupling halves in final accurate alignment is by the use of a dial indicator. Check alignment by straight edge, taper gauge or feelers as accurately as possible by procedure indicated above.

Bolt the indicator to the pump half of the coupling, with the indicator button resting on the other coupling periphery, set the dial to zero, and chalk mark the coupling half at the point where the button rests. For any check, top or bottom or sides, rotate both shafts by the same amount; i.e. all readings on the dial must be made with its button on the chalk mark.

The dial readings will indicate whether the driver has to be raised or lowered or moved to either side. After each movement, check to see that coupling faces remain parallel to one another.

EXAMPLE. If the dial reading at the starting point is set to zero and the diametrically opposite reading at the bottom or sides shows a plus or minus reading of .020 inch, the driver must be raised or lowered by the use of suitable shims, or, moved to one side or the other by half of this reading.

Note: For all checks, including that for parallelism of coupling faces, keep both shafts presssed hard over to one side when taking readings.

Alignment of Gear Type Couplings

Gear type couplings are aligned in the same manner as outlined above. However, the coupling covers must be moved back out of the way and measurements made on the coupling hubs as shown on Figure 6-4.

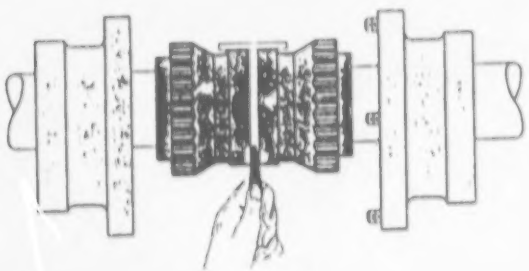


Figure 6-4 Alignment of Gear Type Coupling

Grouting

Grouting compensates for uneveness in the foundation and prevents vibration and shifting after mounting is complete. Build a form around the baseplate to contain the grout and sprinkle area with water to obtain a good bond. The base should be completely filled with a good quality non-shrinking grout. The usual mixture for grouting is one part Portland cement and two parts sand with sufficient water to flow freely. It is also desirable to grout the leveling pieces, shims or wedges in place. Foundation bolts should be tightened when grout has hardened, usually about 48 hours after pouring.

Final Check of Alignment

After the grout has set and the foundation bolts have been properly tightened, the unit should be checked for parallel and angular alignment and, if necessary, corrective measures taken. After the piping of the unit has been connected, the alignment should be again checked.

The direction of rotation of the driver should be checked to make certain that it matches that of the pump. The corresponding direction of rotation of the pump is usually indicated by a direction arrow on the pump casing.

The coupling halves can then be reconnected. With the pump properly primed, the unit then should be operated under normal operating conditions until temperatures have stabilized. It then should be shut down and immediately checked again for alignment of the coupling. All alignment checks must be made with the coupling halves disconnected and again after they are connected.

It should be emphasized that attempts to correct alignment in one direction may alter the alignment in the other direction; therefore, it is necessary to check in all directions after making any adjustments.

After the unit has been running for about one week, the coupling halves should be given a final check for misalignment caused by pipe strains or temperature strains. If the alignment is correct, both pump and driver should be dowelled to the base plate. The location of the dowels is very important and the manufacturer's instructions should be obtained, especially if the unit is subject to temperature changes.

Factors That May Disturb Alignment

The unit should be checked periodically for alignment. If the unit does not stay in line after being properly installed, the following are possible causes:

Settling, seasoning or springing of the foundation.

Pipe strains distorting or shifting the machine.

Wear of the bearings.

Springing of the base plate by heat from an adjacent steam pipe or from a steam turbine.

Shifting of the building structure due to variable loading or other causes.

It may be necessary to slightly re-adjust the alignment, from time to time, while the unit and foundation are new.

Piping

Both suction and discharge pipes should be supported independently near the pump so that when the flange bolts are tightened no strain will be transmitted to the pump casing.

SUBJECT:

PREVENTIVE MAINTENANCE

TOPIC: 7

PUMP MAINTENANCE AND TROUBLESHOOTING

OBJECTIVES:

The trainee will be able to:

1. Recall the basic rules of pump maintenance.
2. Recall the symptoms/check methods for problems which result from:
   (a) Corrosion
   (b) Impeller wear
   (c) Bushing wear
   (d) Misalignment
3. Recall the principal points to be carried out on centrifugal pumps during:
   (a) Weekly maintenance checks
   (b) Six month maintenance checks
   (c) Annual maintenance checks
   (d) Three to five year maintenance checks
4. Recall the checks which should be made on a centrifugal pump during routine maintenance.
5. Recall troubleshooting procedures for:
   (a) Positive displacement pumps
   (b) Centrifugal pumps.

PUMP MAINTENANCE

General

Pumps are designed to operate under a specific set of conditions. Certainly there is some flexibility to these conditions, but within limits; and when those limits are exceeded, the trouble develops unless one does something about it.

The proper approach is to establish an adequate maintenance schedule. Maintenance must be periodic, not spasmodic, and it must be properly timed to cope with the conditions under which the particular pump operates. This is something one must establish through experience. Some maintenance tasks one may find after a time are being performed too often, others not often enough, so adjust the maintenance schedule to suit conditions. As the pump wears, it may be necessary to decrease the time between these periodic maintenance acts. Generally, too often is better than not often enough, except in the case of the lubrication of anti-friction bearings on both motor and pump. Too much lubricant can ruin the bearing as fast or faster than not enough. Check this type of bearing quite frequently until you establish a definite lubrication period.

Finally on this list, no one knows a particular pump better than the man who manufactured it, and no one can tell you better how to handle it. His vast experience in this field is something you buy with the pump, so make the best use of it. If you run into trouble, he is probably the best man to help you out of it. Every pump is provided

with the manufacturer's instructions. These should be retained and studied and used by the operator. If they become lost, they can be replaced. Proper maintenance is the key to obtaining long life and satisfactory performance from a pump. Routine servicing is usually carried out successfully, it is the problems not directly associated with servicing that give most operators trouble. Below are four basic rules for proper pump maintenance:

1. Know the condition of the pump and be able to recognize when something is wrong with it.

2. Make certain that the pump operates under the condition it is designed for.

3. Establish an adequate maintenance schedule.

4. Follow the manufacturer's instructions.

Corrosion

Excessive corrosion, particularly in a deep well turbine is the number one problem. There are instances where the column corroded through and broke off with the bowl assembly ending up in the bottom of the well. Generally before this happens, a hole develops in the column, reducing the output of the pump. If the hole is above the operating water level, you have aeration, iron removal and well fouling.

Pulling the pump periodically in accordance with a preventive maintenance program will let you know the condition of the pump. If the well water is high in dissolved iron, chances are the water is corrosive, requiring servicing possibly every three years. As a good rule, every pump should be overhauled at least once every five years, as by that time the bowl and packing box bushings probably require replacement.

Impeller Wear

Impeller wear or column leakage can be determined by checking the pump's shut-off head. Add the height difference from the water level to the gauge, and compare this with previous readings or the pump curves. This should be done at least monthly and it generally provides fair warning that trouble is brewing below.

Scale

Scale forming in the bowl assembly is a corrosion problem. One should be able to turn the line shaft freely by hand. If after a period of time it becomes stiff, scaling can be suspected; if excessive, a broken line shaft can result. To correct this problem (or to prevent it) remove the pump and clean with inhibited acid, or by mechanical means.

Electrical

Sometimes the utility switches phase on the power distribution system unintentionally, but with sometimes disastrous results. A vertical turbine with a non-reverse ratchet would tend to run backwards and possibly burn out.

The motor starter thermal overloads are not a guarantee that the motor won't burn out. Chances are, when examined, the phase condition has been rectified and the operator will never be the wiser. There was one case where the operator was complaining that the high level alarm was being repeatedly triggered in his sewage pump station. On examination, it was found that the pumps were running in reverse at a greatly reduced capacity. Apparently, a new service hook-up had been completed in the same block and the phases were accidentally reversed. Had the operator checked the shut-off head, he would immediately know if the pump was plugged, worn, or running backward. Shut-off head is generally unaffected in a plugged pump unless the impeller is dragging, in which case the motor load would normally be tripping the starter.

Unbalanced voltages in the distribution system, or one fuse blown on the transformer, can burn out a motor. A three phase motor can keep running on a single phase, but will draw excessive current in the remaining phase and may burn out. All starters should have three phase overload protection. This will minimize burn-outs from fuse failure and unequal supply voltages.

Motor failures can occur from lightning strikes on the power system, particularly in submersible well pumps where an average sized motor is virtually miniaturized so that it can be fitted into a well.

Packing and Seals

It is essential to keep the packing wet. If they leak too much, replace them. Vertical turbines, packing above the lantern ring, usually do not get enough water, and therefore require grease also. If lube service cannot be done regularly, put a spring-loaded lubricator on it.

Be careful not to pack excessive grease into a ball bearing. Clean out all the old grease; apply new grease by flushing through; then remove as much as possible so that when the bearing rotates, the excess grease in the raceways can work out. The balls are supposed to ride on the grease, not plow through it. It takes a lot of energy to push through the grease, and a hot bearing results.

Should an operating vertical turbine gradually increase in vibration and noise after a period of successful operation, and the shaft spins freely and the clearances are correct; probably the lineshaft bushings are excessively worn and the shaft is whipping. Replace bushings before the shaft breaks or exhibits excessive wear.

When water comes up in an oil tube of a vertical turbine oil lube pump, either the bottom seal is lost or there is a hole or leak in the oil tube. Pull the pump before the lineshaft seizes and breaks. Oil libe verticals do not operate well as water lube pumps.

Sand and Soil

Vertical well pumps, especially submersible ones, are not really meant to pump sand and grit. A submersible turbine has its seal facing upwards in a little catchment area of the pump inlet where sand and grit can collect. If this is a problem, use an oil lube pump with closed impellers and avoid submersibles. Submersible sewage pumps have an advantage in this regard, as the seal faces downwards and is behind the impeller where grit is avoided. There are various designs of pumps used (with only some success) to avoid this.

Plugging

Sewage pumps will plug occasionally, generally because stringy material becomes enwrapped around the impeller. In dry pit type pumps, this can be removed through the volute hand hole cover by peeling or cutting away the material. In a submersible pump, care should be taken to remove this material, particularly if it has lodged behind the impeller. Remove the impeller rather than chance breaking the mechanical seal. Also examine the seal carefully for damage. A leaking seal in a submersible generally precedes a motor re-wind.

Misalignment

In some cases, misalignment of motor and pumps causes vibration and mechanical failure. Misalignment will produce a noise at the same frequency of the motor, or an octave of it, whereas bearing noise will be random. There are instruments available to check this but they are too

expensive to have on hand at each plant, one should train himself to identify the difference in sound.

There are two types of misalignment:

1. The offset where two abutting shafts are at different elevations. This can be determined by attaching a dial gauge on one shaft and rotating it to determine the offset.

2. Angular misalignment, where the two end shafts abutt like a hinge, but rotate in different planes. Again use a dial gauge fastened to one shaft, and rotate both shafts together to check misalignment.

Don't rely on flexible couplings. These are required for heat growth of the motor, aligned to within 0.001 of an inch, when motor is at running temperature. Vertical turbine shafts are checked simply by attaching the dial gauge to the motor case and revolving the shaft. If out by more than one or two-thousandths, remove motor and tap with soft head hammer to align.

Maintenance Scheduling

The following is a suggested schedule for all centrifugal pumps:

1. Weekly or Monthly - Check bearing temperature with a thermometer or your hand. If anti-friction bearings are running hot, they probably have too much libricant. If sleeve bearings are running too hot, they probably need more lubricant. If change

in lubrication does not correct the condition, disassemble and inspect the bearing. Alignment of pump and motor should be checked also, if overheating occurs.

2. Six Months - Drain lubricant, wash out oil wells and bearings with kerosene. In the case of sleeve bearings, check to see that oil rings are free to turn with the shaft. Refill with the lubricant recommended by the pump manufacturer. Flush grease anti-friction bearing (ball or roller bearings), but first remove old grease, flush in new and then remove excess, permit expansion room.

3. Yearly - Replace pump packing. Use grade recommended by the pump manufacturer. Be sure that seal cages are centered in stuffing boxes at the entrance of water seal piping. Although stuffing box is the term applied to the pump packing case, just stuffing in the packing, as the name implies, is not the proper approach. Packing should be cut in rings exactly the same diameter of the shaft and be placed in the stuffing box one at a time. Joints in consecutive rings should be staggered to minimize leakage. Each ring should be sealed tightly, but not rammed into place. Check shaft sleeves for scoring that would accelerate packing wear and replace sleeves if needed.

Measure bearings for wear and replace if excessive. Generally, allow two-thousandths of an inch clearance, plus one-thousandth of an inch for each fraction of an inch of shaft journal diameter.

Check alignment of pump and motor and shim up units as needed. If misalignment occurs frequently, check the piping system. Unbolt piping at suction and discharge nozzles and observe if it springs away. This will indicate strain on the casing. Make certain that the pipe supports take the load and not the pump.

4. Three to Five Years - Remove the rotating element and inspect for wear, pitting, etc. Check wearing ring clearance. Generally, there should be no more than three-thousandths of an inch per inch of wearing ring diameter. Remove any deposit or scaling from the impeller and casing.

   Measure total suction and discharge lifts with gauges and compare them with the original design conditions.

Routine Maintenance

If possible one should check the pumps more often than once a month, every week, or several times a week. There are a number of things one can do quickly and with little effort that will ensure with fair certainty, that the unit operates properly.

1. Check discharge pressure, make certain that it is maintained in the normal operating range of the pump.

2. Check shaft packing and make certain that a small flow of water issues from it. If flow is too great, tighten gland until the flow is reduced to the proper amount. If no flow exists, try to relieve pressure on the packing to produce a water flow and replace packing if necessary. A water flow is necessary to lubricate the shaft through the stuffing box. Scoring of the shaft will soon result if it does not obtain proper lubrication.

3. Check the motor and pump for excessive vibration while under load.

4. Make certain that proper suction conditions are maintained. A vacuum gauge on the pump inlet will be most useful when a suction lift exists.

5. Keep the suction inlet clean of debris. A clogged suction screen will cause a sharp capacity drop, vibration of the pump, and sometimes overheating of the motor.

6. Make certain that the pump does not operate against shut-off head for long periods. This will result in overheating of the pump and possibly pump seizure if the conditions persist long enough.

7. On deep well type pumps with oil lubrication, make certain that the oil reservoirs are filled periodically, also check occasionally to ascertain that the rate of oil feed is properly adjusted.

8. Make certain that the pumphouse or enclosure is properly ventilated during warm periods and properly heated during cold weather.

9. Check the Operation of automatic control devices periodically, and make certain that their operation is dependable, and that they are not hunting.

The above test applies generally to all centrifugal type pumps. Variation in construction and application will occur from one installation to the next, which will necessitate more attention than others. These are almost certain to be covered in the manufacturer's instruction manual.

PUMP TROUBLESHOOTING

Positive Displacement Pumps

Positive displacement pumps fall into two types: "reciprocating" and "rotary". The more commonly used reciprocating pumps are "plunger" and "diaphragm" pumps. Rotary positive displacement pumps are available in a much wider variety and are less well known. These are gear, vane, lobe, screw, etc. Each type can also be obtained with certain variations such as sliding vane, swinging vane, double and triple lobe, double and triple screw, eccentric piston.

Positive displacement pumps however have a common denominator. They require protective devices not required on the centrifugal pump. Protective devices include a pressure-relief valve or a shear-pin coupling or both. In the event of a blocked discharge or closed valve either of the protective devices should operate.

It is the protective devices that complicate trouble-shooting problems on positive displacement pumps, and which underline the necessity for consulting the manufacturer's manual of instructions so that the proper corrective action may be taken. In addition, the following trouble-shooting procedures may be helpful.

1. Pump - Fails to Deliver Liquid

   a. Suction and/or discharge line blocked.
   b. Suction and/or discharge valve closed.
   c. Suction lift too high.
   d. Ball (automatic) valve on intake not closing on discharge stroke (Reciprocating).
   e. Ball (automatic) valve or discharge not closing on suction stroke (Reciprocating).

2. Pump Capacity Below Rating - Check previous points plus:

   1. Leaks around plunger.
   2. Leak through diaphragm.
   3. Stroke too short.
   4. Ball (automatic) valves - intake and/or discharge leaking.

3. Vibration and Noise

   1. Misalignment.
   2. Unstable foundation, loose anchor bolts.
   3. Unbalance, one or more plungers not working (unloaded).
   4. Worn bearings, bent shaft, damage coupling, etc.
   5. Loose fittings on line valves.

4. Overload of Driver: Check 1 to 4 above and in addition:

   1. Pumping over design head.
   2. Failure of pump protective devices - shear-pin, pressure relief valve.
   3. Packing too tight around plunger.
   4. Discharge line restricted or discharge valve not fully open.
   5. Ball (automatic) valve - discharge not opening to full extent.

5. Overheated Bearings: Refer to Centrifugal Pump Trouble Shooting.

Centrifugal Pumps

1. Pump Fails to Deliver Liquid

   a. Pump not properly primed or vented.
   b. Discharge and/or suction valve not properly adjusted-open.
   c. Check valve not opening.
   d. High spot or air pocket in suction line.
   e. Pump speed too low.
   f. Excessive suction lift or inadquate submergence of suction.
   g. Impeller clogged.
   h. Incorrect direction of rotation.
   i. Impeller mounted backwards on shaft.

2. Pump Capacity Below Rating:

Check previous points and in addition:

1. Air leaks in suction line or stuffing box.
2. Entrained air or gas in liquid being handled.
3. Worn wearing (seal) rings.
4. Damaged impeller.
5. Defective packing of shaft seal.
6. Foot valve or suction line too small.
7. Check valve not properly opening.

3. Loss of Prime

1. Air leak in suction piping or stuffing box.
2. Excessive suction lift or insufficient submergence of suction.
3. Entrained air or gas in liquid being handled.
4. Water seal in stuffing box not functioning.

4. Vibration and Noise:

1. Misalignment.
2. Unstable foundation.
3. Material in pump causing imbalance.
4. Worn bearings.
5. Damaged impeller - imbalance.
6. Bent shaft.
7. Worn or damaged coupling.
8. Air bound-pump not properly primed.
9. Suction lift too high.
10. Loose valve fitting in line.

5. Overheated Bearing:

1. Too much grease in ball bearing or insufficient oil.
2. Misalignment.
3. Damaged impeller or clearance (seal) rings.
4. Bent shaft.
5. Abnormal end thrust.
6. Dirt in bearings.
7. Excessive belt tention.

6. Overload of Driver:

1. Speed too high.
2. Pumping over capacity due to existing head being lower than rated head.
3. Packing too tight or defective.
4. Wearing rings (seal) worn.
5. Bent shaft.
6. Misalignment.
7. Rotor wedging or bending.
8. Faulty bearings.

SUBJECT: PREVENTIVE MAINTENANCE

TOPIC: 8 PUMP PACKING AND SEALS

OBJECTIVES:

The trainee will be able to:

1. Recall the various types of compression packings along with the individual characteristics.
2. Recall the guides to packing selection.
3. Recall the procedure for installation of pump packing.
4. Recall the procedure for packing valves.
5. Recall the common packing failures.
6. Recall the mechanical seal-
   (a) the components
   (b) the types
   (c) the factors governing selection.
7. Recall the installation precautions for mechanical seals.

PUMP PACKING AND SEALS

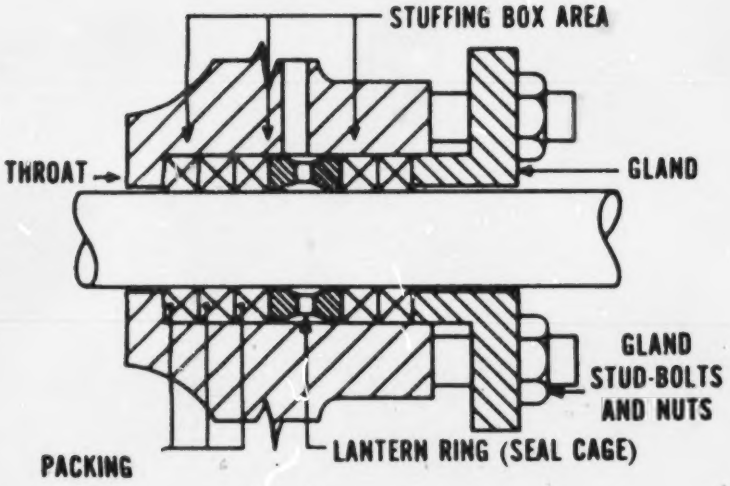
The choice of the particular type of pump packing or seal is dictated by the manufacturer's engineering design personnel. This workshop will discuss compression type packings and mechanical seals.

COMPRESSION PACKINGS

Compression packings are often referred to as soft packings or jam packings because they are packed into a stuffing box where their fit is regulated by compression from the gland or follower. A stuffing box (Figure 8-1) is the cylindrical cavity surrounding the point of shaft entry, which is fitted with a means of throttling leakage through it.

Packings are used as sealing elements in such equipment as centrifugal pumps, rotary pumps, reciprocating pumps and in industrial bronze, iron and steel valves as well as faucet valves. Where there is relatively no motion, slow or infrequent motion, such as in valves, packings can seal without leakage. Where rapid motion occurs, rotating or reciprocating, such as in centrifugal pumps, packings must permit leakage for lubrication, thus ensuring cool operation.

Pump packings (Figure 8-2) have an impregnant built into them which acts as a primary lubricant for the start up and the break-in adjustment. During this period a certain amount of the primary lubricant is lost. Once the pump is on stream, external lubrication must be supplied to the packing to keep it running properly and to attain long life. If not, the primary lubricant in the packing will bleed out, friction will increase with the attendant generation of heat, the primary cause of packing failure. Compression packings are expendable materials which are expected to wear out in preference to shafts and shaft sleeves which are thus preserved.



TYPICAL STUFFING BOX ARRANGEMENT AND DESCRIPTION OF PARTS

Figure 8-1 Stuffing Box

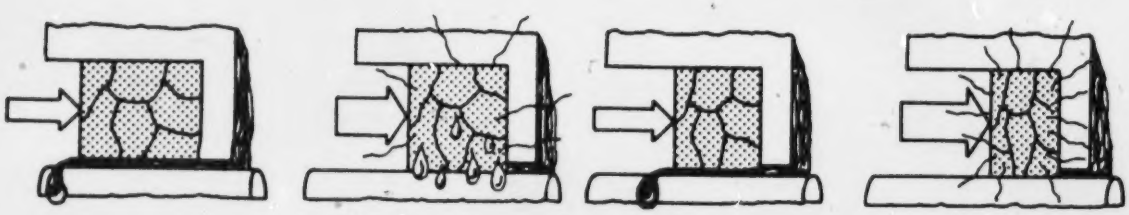


Figure 8-2 New Packings are Saturated with an "Emergency" Lubricant for Initial Break-in.

When the pump suction pressure is above atmospheric pressure the pumped liquid lubricates the packing. (Figure 8-3). If this pressure is below atmospheric pressure fluid may not reach the packing. Thus a lantern ring is employed and lubrication is supplied through a piping arrangement from the pump discharge pressure. (Figure 8-4). These conditions are both employed when pumping clear liquids. When pumping slurries an external source of clear liquid which is at a higher pressure than the slurry must be force-fed into the lantern ring. Two methods of handling slurry, in current use, are shown in Figures 8-5a and 8-5b.

A valve, expansion joint, autoclave doors and other basically static applications are packed differently than a pump. In contrast to a pump packing, which must leak, a valve packing must not leak.

Compression packings used in valves, expansion joints, autoclaves and other static types of applications function like a gasket, as compared to a pump packing which must both seal to a degree and carry lubricant for rotating or reciprocating shafts. Valve stem packings must provide a dense structure that will not permit movement of the liquid or gas through the body of the packing itself.

For a shaft or rod in motion, be it rotating or reciprocating, choose a packing that has a primary lubricant in it. Then, when the equipment is on stream, make sure the packing has supplemental lubrication from either the pumped fluid or an external fluid. If the application is static, such as valve stems, expansion joints, etc., make sure that packing has a stable lubricant in it that won't ooze out or dry out due to pressure/temperature condition of the process fluid.

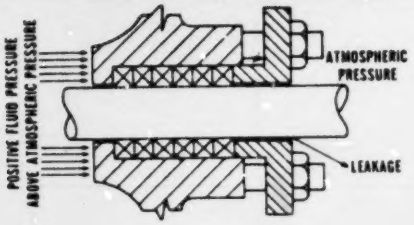


Figure 8-3 Typical Stuffing Box when Pump Suction Pressure is Above Atmospheric Pressure.

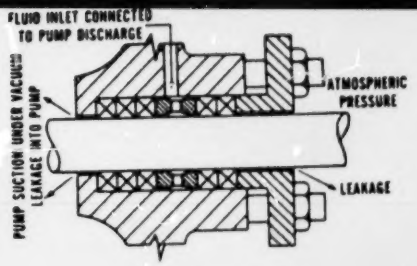


Figure 8-4 Typical Stuffing Box when Pump Suction Pressure is Below Atmospheric Pressure.

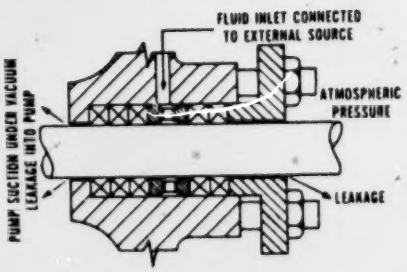


Figure 8-5(a) Typical Stuffing Box when Pump is Pumping Slurries.

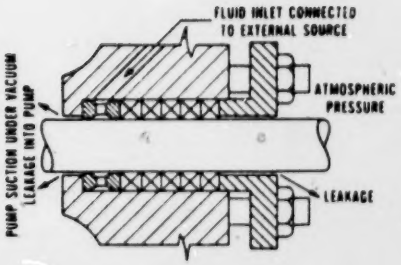


Figure 8-5(b) Another Type Stuffing Box when Pump is Pumping Slurries

Various Types of Compression Packing

Compression packings are made in a variety of shapes, sizes and constructions, from numerous types of materials. Certain types of these soft packings have evolved over the years that best suit specific applications. A knowledge of these types of packings, along with their equipment usage, will prevent misapplication and will reduce maintenance down-time.

1. Types of Braided Packings

   Engineers and maintenance men often refer to "braided" packings. This is not sufficient as there are several types of braided packings on the market.

   The most popular braided packings used on rotating equipment are square interbraid, square plaited, braid-over-braid and braid-over-core types. Of these four, the square plaited are most popular. Each is made on a different type of braiding machine and has a certain amount of strength because of the braid pattern. The following shows the braid patterns and typical usage on rotating pumps.

   a) Square Interbraid

   Actually formed square, with yarns diagonally braided, will retain square shape more than braid-over-braid.

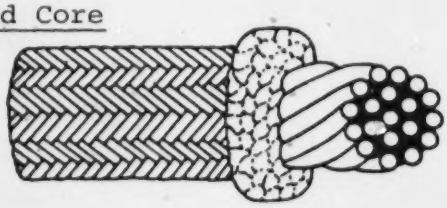
b) Square Braid (Plaited)

Soft, absorbent structure can carry high amount of lubricant.

c) Braid-Over-Braid

Braided round, then calendered square. Very dense because of individual jacket-over-jacket construction.

d) Braid-Over-Twisted Core



Braided round, then calendered square. Can carry high amount of lubricant.

These four different types of braided structures can be made from a variety of materials. White chrysotile asbestos is the most popular. (For more detailed information on asbestos products refer to the "Handbook of Asbestos Textiles" by the Asbestos Textile Institute, third Edition, 1967). Most braided packings used on rotating shafts are made from white chrysotile asbestos yarn. Under certain conditions, such as mechanical vibration or excessive gland clearances, it may be necessary to use yarn reinforced with metal. Normally,

copper or brass wire inserted yarns are used. When clearances at the bottom or top of the stuffing box are too great, extrusion of the packing can occur, and then lead or other metallic bull rings are used. Blue African crocidolite asbestos is also used in addition to other materials such as ramie, flax, cotton, teflon filament yarns, graphite filament yarns, graphite filament yarns, and in some cases metal wire and metal ribbon.

Packing manufacturers impregnate the yarns and/or various braided structures with lubricants that will withstand temperature and washout from the pumped fluid, as well as provide lubrication for the break-in and start-up periods. Once on stream, the pumped fluid must lubricate the packing.

Since packings are used against water, steam, oil, acids, caustics, gasolines, food, beverages, etc., it is only natural that the manufacturer must have several types of primary lubricants to resist pumped fluid wash-out.

2. Metallic Packings (Figure 8-6)

Metal packings of lead, copper, alumium, phosphor bronze and nickel are now made either spirally wrapped or in a folded, twisted construction, often around a resilient or compressible core. Both types are ordinarily oiled and graphited, although they may be furnished dry for special applications. Endless spun and compressed lead rings form a superior condenser packing and also have other uses as gaskets, end rings, etc. One of the first flexible metallic rings was the spirally-wrapped type which is still used

for heavy pressure duty work. Metal and fabric packings are generally lead, copper or aluminum over braided or twisted asbestos or braided flax.

Metal and plastic packings normally have lead foil over a plastic core but may be a braided metal wire over plastic.

Metal and resilient elastomer-core packings such as channel packings combine metal and fabric on the face only. Metallic cores may be lead or copper. Lead is usually spirally wrapped, while copper is a braided wire.

3. Plastic Packings (Figure 8-7)
Lubricated plastic packings contain asbestos fiber, graphite or mica, oil or grease. Some contain metal particles. Others also contain wood particles which form additional lubricant reservoirs. These packings are sold

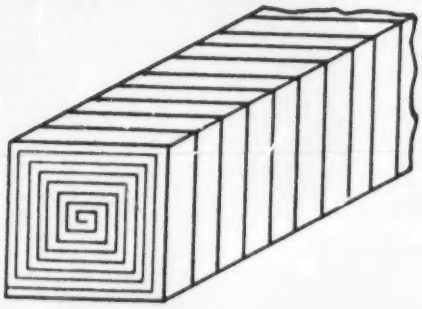
a) in bulk

b) in sticks for injection by heavy duty screw-type guns

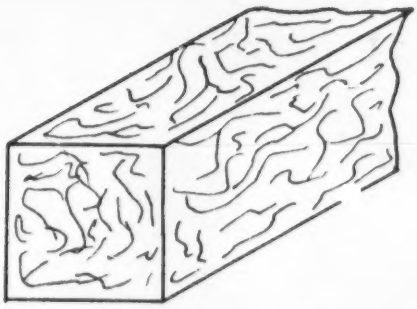
(c) enclosed in a braided jacket
   (i) open cotton thread for handling only
   (ii) asbestos jacket to help retain packing in a stuffing box
   (iii) short lengths in braided cotton tubing

(d) die formed rings.

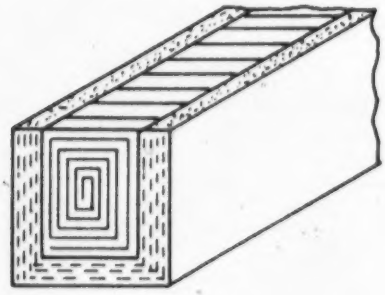
These packings are useful where packing must supply a part or all of the lubrication. For medium and high speed rotary service, additional lubrication or cooling is usually necessary.



METALLIC
(SPIRALLY WRAPPED)

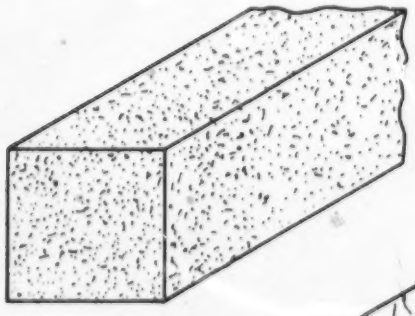


METALLIC
(TWISTED AND FOLDED)

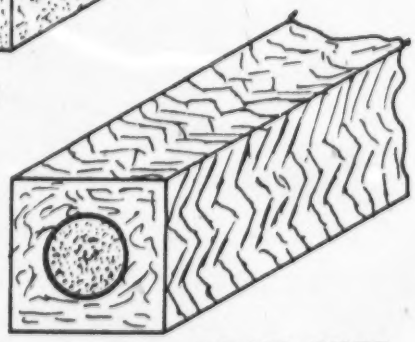


CHANNEL
(METALLIC FACE)

Figure 8-6 Metallic Packings



PLASTIC



BRAID OVER
PLASTIC CORE

Figure 8-7 Plastic Packings

The second type of plastic packing is the dry bonded type which has a composition similar to the lubricated type except that an elastromeric binder is used instead of a lubricant. Asbestos fiber and graphite or mica with or without metal particles, depending on the type and temperature of service, are bonded with natural rubber or Neoprene. Small amounts of lubricant are used, but function only as softeners and do not reach the shaft to serve as a lubricant. Like the lubricated types, these styles are available in different forms.

a) Bulk

b) Flat coils or spirals.

Plastic packings can be supplied with a plain or wire reinforced asbestos jacket to enable the sealing of higher pressures with one style of packing.

4. Rubber and Duck Packings

Rubber and Duck types are made by laminating plies of cotton duck which has been treated with a rubber compound. They are normally press-cured in slab form and then cut in strips of a desired size. Then they are generally impregnated with oil and given a graphite finish. These packings are generally used on the liquid ends of reciprocating services, such as rams or pistons. The rubbers commonly used are natural, Neoprene, and SBR.

5. Asbestos Fabric Packings

Asbestos fabric constructions are recommended for

use on reciprocating pumps on the steam end. These packings may have a round core or rectangular back of rubber. The rubberized asbestos cloth is folded or rolled on itself or on the core or rubber back to the required size. It is then vulcanized, lubricated with vegetable oil and given a graphite finish.

6. Die Formed Rings

Die formed rings and die formed combination sets of packing are often used because

a) The rings are die formed to the exact size of the stuffing box.

b) The exact number of rings to fit a stuffing box eliminates guesswork.

c) No waste due to inaccurate cutting of rings from spools.

d) Repack stuffing boxes faster--reduces downtime.

7. Channel Packings

Another type would be a channel packing where a channel made either of asbestos or duck cloth with a metallic face of either lead or copper is used. This style is very effective on high pressure reciprocating applications for either steam or hydrocarbons.

8. Lubricants Used in Packings

To meet the chemical and mechanical conditions, packing manufacturers use both solid and fluid lubricants. Commonly used solid lubricants include TFE, graphite, mica and molydisulphide. Fluid lubricants include oil, greases and

waxes--of animal, petroleum, vegetable and synthetic types.

Guide to Packing Selection

Probably one of the most frustrating tasks of maintenance personnel is how to select a certain type of compression packing for a given application. The manufacturers' catalogs may list anywhere from a few styles up to 80 or 90 types. If some general basic understanding of compression packing selection is known, then selection becomes less complex.

Where conditions are not severe and pressures are low, a single type of soft plastic packing or fabric packing can be used successfully. But as pressures increase it is often advisable to include a more dense packing, such as a braided type of asbestos or metallic packing to support the soft plastic rings. One ring of these more dense materials would be used at the bottom of the box and another under the gland to prevent extrusion of the soft materials at these two points. For the same reason, if a lantern ring is used the dense packing is used on both sides of the lantern ring. As operating pressures increase, a greater number of these more dense rings are used in the stuffing box with a decreasing number of the softer, more sensitive packings.

With the large use of centrifugal and rotary pumps in industries today, packing selection for this equipment becomes of utmost importance. Tied in directly with this is the selection of packings for valves. Thus probably 75% of packing applications boil down to rotating pumps and valves.

To determine which packings should be used there are certain basic questions that must be answered and these determinants are as follows:

1. Dimensions
2. Fluid or gas handled
3. Stuffing box temperature

4. Stuffing box pressure

5. Type of motion

6. Speed

7. Shaft or rod material

8. Cycles

9. Mechanical condition of equipment (shaft, bore, etc.)

10. Special requirements.

Rather than attempt to make your own choice of packing material, it is advisable that the above information be made available to a packing supplier or manufacturer.

INSTALLATION OF PACKINGS

Packing the Pump Correctly

The importance of packing the pump correctly cannot be overemphasized. Many packing failures are due to incorrect installation of the packing. There is one correct way to pack a pump which is as follows.

1. Remove all old packing from the stuffing box. Clean box and shaft thoroughly and examine shaft or sleeve to see if wear is excessive. Check bearing by lifting shaft up and down: do not expect packing to act as a bearing.

2. Use the right cross-section of packing or pre formed rings to be sure the packing will fit and can compensate for shaft wear, if any. To determine the correct packing size, measure the diameter of the shaft (inside the stuffing box area if possible) and then measure the inside diameter of the stuffing box itself (to give the O.D. of the ring). Subtract the I.D. measurement (the shaft diameter) from the O.D. measurement and divide by two. The result is the required size.

Standard compression packings are generally made up in increments of 1/16" from the smallest size available. For most applications, if the calculated size figures under 1/16", it is best to use the next size larger. Thus, if the shaft measures 2 1/2" and the inside of the stuffing box 3 7/16" (giving a packing space of 15/16"), the size of coil packing to use would be 1/2" rather than 7/16".

3. When using coil or spiral packing always cut the packing into separate rings. Never wind a coil of packing into a stuffing box. Rings can be cut either with butt (square) joint or diagonal joints depending on the method used for cutting.

The best way to cut packing rings is to cut them on a mandrel the same diameter as the shaft in the stuffing box area. If there is no shaft wear, rings can be cut on the shaft outside the stuffing box if there is room.

Hold the coil packing tightly and firmly on the mandrel but do not stretch excessively. Cut the ring and try it in the stuffing box to make certain it fills the packing space properly with no gap in the joint at the O.D. of the ring.

Each ring can be cut in the same manner or the first ring can be used as a master from which the balance of the rings are cut. If the butt rings are cut on a flat surface be

certain that the side of the master rings and not the O.D. or I.D. surface is laid on the rings to be cut; this is necessary so that the slight bevel at the end of the rings be reproduced. Remember the O.D. circumference of the ring is greater than the I.D. circumference. When cutting diagonal joints use a maple miter board so that each successive ring can be cut at the correct angle.

It is necessary that the rings be cut to the correct size, otherwise service life is reduced. This is where die formed rings are of great advantage as they give you the exact size ring for the I.D. of the shaft and O.D. of the stuffing box and there is no waste because of incorrectly cut rings.

4. To cut rings from a packing that is unusually soft or that has a tendency to fray excessively, it is advisable to apply a small piece of tape at the point where the cut is to be made, then cut through the tape. If the tape is thin it can be left on the ring.

5. Install one ring at a time. Make sure it is clean and has not picked up any dirt in handling. If clean oil is available, lubricate the shaft and the inside of the stuffing box. Seat rings firmly . Joints of successive rings should be staggered and kept at least 90° apart. Each individual ring should be firmly seated with a tamping tool. When enough rings have been individually seated so the nose of the gland will reach them, individual tamping should be supplemented by the gland. Never depend entirely on the

gland to seat a set of rings properly--this practice will jam the last rings installed but leave the bottom rings loose in the box. The result is excessive and rapid wear of outer rings, erratic packing performance; sometimes twisting and tearing of the bottom rings because they are loose in the stuffing box.

6. *After the last ring is installed, take up bolts finger tight or very slightly snugged up. Do not jam the packing into place by excessive gland loading. Start pump, and take up bolts until leakage is decreased to a tolerable minimum. Make sure gland bolts are taken up evenly. Stopping leakage entirely at this point will cause the packing to burn up.*

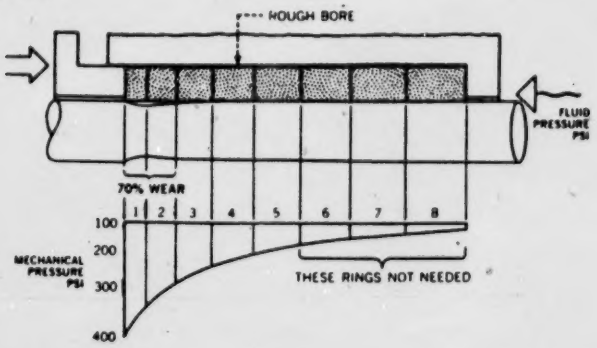
7. *Allow packing to leak freely when starting* up a newly packed pump. Excessive leakage during the first hour of operation will result in a better packing job over a longer period of time. Take up gradually on the gland as the packing seats until leakage is reduced to a tolerable level. *Never try to stop leakage entirely.*

8. When specified by the pump manufacturer, provide means of lubricating the shaft and packing through a lantern ring by supplying water, oil, grease or liquid handled in the pump. Fittings for this purpose are standard on many pumps.

9. If the stuffing box has a lantern ring (see illustration), make sure the lantern ring, as installed, is slightly outboard of the fluid inlet so it will move in line with the inlet as follower pressure is applied.

10. Replace packing when leakage cannot be controlled by further take-up on the follower.

11. On both centrifugal and reciprocating pumps about 70° of wear is on the outer two packing rings nearest the gland. However, each additional ring does throttle some fluid pressure. And on most machines there must be enough rings so if one fails another does the sealing and the machine need not be shut down.



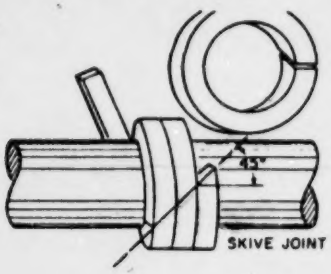
The mechanical pressure curve above shows eight packing ringsonly about five of which are needed, according to the pressure curve, as the bottom three do little sealing. The advantage of using fewer rings is less rod wear, and the stuffing box design is simpler, takes less material. But wear isn't the only problem. With high temperatures, high pressures, corrosive chemicals or abrasive particles in the fluid, more rings may be the only solution for some services. In such cases, the bottom ring contacting the casing fluid may take most of the beating from these severe service conditions.

Packing Valves Correctly

As with pump packing, the first step to getting the most out of a valve packing is correct installation. Here

is the right way to pack valves:

1. Carefully perform all the operations outlined under steps 1, 2, 3, 4, and 5, as given for pumps and agitators. Rings used on valves and expansion joints are generally cut with a bevel joint (illustrated below).



In preparing bevel cut (45°) rings, be sure the first ring is carefully cut and then tested on the stem.

2. *Bring the follower down on the packing to the point where heavy resistance to wrenching is felt. During this time turn valve stem back and forth to determine ease of turning. Do not torque down to the point where the stem wont't turn.*

TROUBLESHOOTING PACKING FAILURES

Packings may fail for a variety of reasons. Besides improper installation, packing failures are often due to worn or faulty equipment, shaft misalignment, shaft whip, bearing misalignment, uneven take-up on the gland bolts and other causes.

If you are having trouble, carefully remove and examine the old packing set. Do not throw the set away because it often gives clues as to the condition of the equipment....and may be the means of solving the problem. The following clues and possible troubles were found by

examining sets of packing which failed in service:

1. Clue: Excessive reduction in cross-section of packing directly beneath rod, shaft or plunger.

   Possible Trouble: Low bearings with shaft or rod riding on packing. In service early leakage occurs around the top of the shaft or rod.

2. Clue: Excessive reduction in thickness of packing directly over or on either side of rod or shaft.

   Possible Trouble: Rod or plunger out of alignment, and in the case of the rod or shaft, the bearings may be badly worn, causing whipping of the shaft.

3. Clue: Part of one or more rings missing from set.

   Possible Trouble: Bottom of stuffing box badly worn, with packing being extruded into system. Considerable difficulty, such as packing getting into valves, traps or contaminating fluid handled, may result.

4. Clue: Axial bulge in one or more rings.

   Possible Trouble: Adjacent rings cut too short or too long, causing packing under pressure to be deformed.

5. Clue: Packings showing tendency to sheet out or extrude between rod or shaft and the gland follower.

Possible Trouble: Excessive gland bolt pressure. Too much clearance between the shaft and the gland follower.

6. Clue: Rings next to gland followers badly deformed with bottom rings in fair condition.

   Possible Trouble: Improper installation of packings and excessive gland bolt pressure used.

7. Clue: Wearing face of rings dried and charred with rest of packing in good condition.

   Possible Trouble: High temperatures and lack of adequate lubrication.

8. Clue: Innermost ring deteriorated.

   Possible Trouble: Packing incompatible with fluid handled.

MECHANICAL SEALS

A mechanical seal is a sealing device which forms a running seal between rotating and stationary parts. The design of liquid handling equipment with rotating parts today would include the consideration for the use of mechanical seals. Advantages over conventional packing are as follows:

1. Reduced friction and power losses.
2. Zero or limited leakage of product.
3. Elimination of shaft or sleeve wear.
4. Reduced maintenance.

The wide variety of styles and designs together with extensive experience allows the use of seals on any sealing problem.

A mechanical seal must seal at three points.

1. Static seal between the stationary part and the housing.

2. Static seal between the rotary part and the shaft.

3. Dynamic seal between the rotating seal face and the stationary seal face.

Components of Mechanical Seal

Figure 8-7 shows a basic seal with these components.

1. Stationary seal part-positioned in the housing with preload on the "O" ring to effect sealing and prevent rotation.

2. Rotating seal part-positioned on the shaft by the "O" ring. The "O" ring seals between it and the shaft and provides resiliency.

3. The mating faces--The faces are precisioned lapped for a flatness of 3 light bands and a surface finish of 5 microinches.

4. Spring Assembly--Rotates with the shaft and provides pressure to keep the mating faces together during periods of shut down or lack of hydraulic pressure.

5. Driving member positions the spring assembly and the rotating face. It also provides the positive drive between shaft and the other rotating parts.

6. End movement--As wear takes place between the mating faces the rotating face must move along the shaft to maintain contact with stationary face. The "O" ring must be free to move.

A mechanical seal operates as each basic component performs its duty. Liquid pressure in the seal chamber forces the faces together and provides a thin film of lubricant between them. The faces, selected for low frictional qualities, are the only rubbing parts. These basic components are a part of every seal. The form, shape, style and design will vary greatly depending upon service and manufacture. The basic theory, however, remains the same.

Types of Mechanical Seals

Mechanical seals can be classified into the general types and arrangements shown below. Understanding these classes provides the first step in proper seal selection.

Single seals

Inside, outside,

Double seals

Single Seals, Inside unbalanced Figure 8-9

The single inside seal mounts on the shaft or sleeve within the stuffing box housing. The pumpage is in direct contact with all parts of the seal and provides the

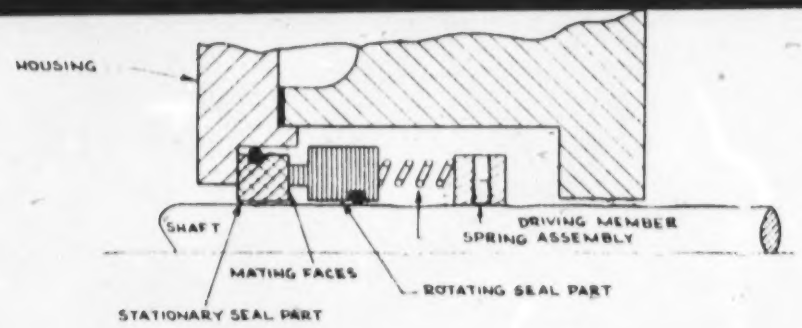


Figure 8-8 Basic Mechanical Seal

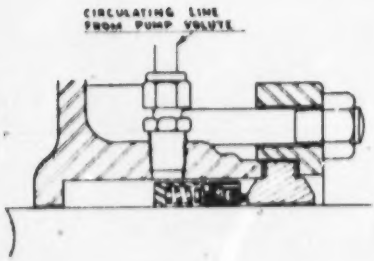


Figure 8-9 Single Seals, Inside unbalanced

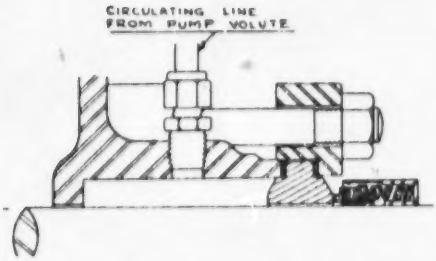


Figure 8-10 Single Seals, Outside unbalanced

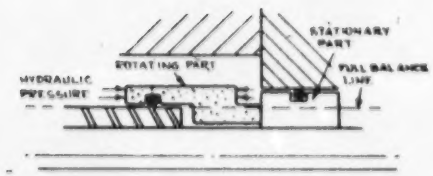


Figure 8-11 Single Seals, balanced

lubrication for the faces. The full force of pressure in the box acts on the faces providing good sealing to approximately 200 P.S.I.G. This is the most widely used type for services handling clear liquids. A circulation or by-pass line connected from the volute to the stuffing box provides continual flushing of the seal chamber.

Single Seals, Outside unbalanced (Figure 8-10)

This type mounts with the rotary part outside of the stuffing box. The springs and drive element are not in contact with the pumpage, thus reducing corrosion problems and preventing product accumulation in the springs. Pressures are limited to the spring rating, usually 35 P.S.I.G. Usually the same style seal can be mounted inside or outside. The outside seal is easier to install, adjust and maintain.

Single Seals, balanced (Figure 8-11)

Balancing a seal varies the face loading exerted by the box pressure, thus extending the pressure limits of the seal. A balanced rotating part utilizes a stepped face and a sleeve. Balanced seals are used to pressures of 2000 P.S.I.G. Their use is also extensive on light hydrocarbons which tend to vaporize easily.

Balanced outside seals allow box pressure to be exerted toward the seal faces, thus allowing pressure ranges to above 150 P.S.I. as compared to the 35 P.S.I.G. limit for the unbalanced outside seal.

Double Seals

Double seals use two seals mounted back to back in the stuffing box. The box is pressurized with a clear liquid from an outside source. These seals are used extensively on slurry service.

Selection of Mechanical Seals

The proper selection of a mechanical seal can be made only if the full operating conditions are known. These conditions are as follows:

1. Liquid
2. Temperature
3. Characteristics of liquid.
4. Pump Model

1. Liquid

   Identification of the exact liquid to be handled provides the first step in seal selection. The metal parts must be corrosion resistant. These parts usually available in steel, bronze, stainless steel, or Hastelloy provide a wide choice to meet specific services.

   The mating faces must also resist both corrosion and wear. Carbon, glass-filled Teflon, Stellite or tungsten carbide allow use of a variety of materials which offer both excellent wear properties and corrosion resistance.

   Available sealing members of synthetic rubber, asbestos and Teflon complete the proper material selection.

2. Temperature

   The temperature will in part determine the use of the sealing members. Synthetic rubbers are used to approximately 120°C., Teflon to 260°C., and asbestos to 340°C. Cooling the liquid in the seal chamber by water cooling jackets or cool liquid flushing, often extends seal life and allows wider selection of materials.

3. Characteristics of Liquid

Abrasive liquids create excessive wear and short seal life. Double seals or clear liquid flushing from an external source allows the use of mechanical seals on these difficult liquids. On light hydrocarbons balanced seals are often used even though pressures are low to promote longer seal life.

4. Pump Model

Mechanical seal selection, installation and application varies with the pump model. All seals do not fit all pumps. Pump discharge pressures and temperatures are not necessarily the design conditions for the seal. Consult your pump sales engineer for selection of the proper seal for the service.

Installation Precautions

Protect all flexible members, as well as the seal faces. When passing the flexible members over sleeves, shafts, nuts, etc., cover threaded areas with paper or tape before sliding seal parts past, and check to be sure all burrs are removed and a small radius exists on the shaft sleeve ends. A light film of oil on sleeve surfaces will help greatly.

Check position of set collar, if used, to be sure that seal is confined to predetermined length when installed. When fitting single suction pumps with rubber bellow-type seals only, slide bellows on until it contacts its spring mechanism so that final step of mounting rotor in casing and tightening gland plate will push bellows to proper position. (Don't stop half way through this job.) Bellows will adhere to shaft in position thus established and seal relies on bellows to prevent leakage between itself and the shaft or sleeve.

With double suction pumps, the seals have to be first put on the rotating element, and later on, this element is assembled in the casing. This can require too much elapsed time before the gland plates can be pulled into position. Therefore, it is well to make up a split collar to use instead of the gland plate, to position the seals with assembling on the rotating element. These collars are then removed and the gland plates pulled up when the element is assembled.

Mechanical seals are one item which should not be submitted to routine inspection maintenance. In operation the seal faces "wear in" with respect to each other, and if disturbed, it may not be possible to get them reseated. It is good practice to maintain a set of spare seal faces so that when pump maintenance causes the seals to be moved to get at other parts of the pump, these faces can be replaced.

Used faces can be replaced if returned to the seal supplier. The economy of this will depend on how special or large the seal may be. Roughly, if the seal is over 2 inches in size, relapping gets practical.

Also, if the seal is of the bellows type, spare bellows ought to be kept on hand.

A closing word about seals: insist that their lubrication be kept constant, clean and cool. Pressure must be slightly more than the differential across the seal. The seal liquid must have lubricating properties.

By keeping the sealant below 65^{o}C., seals will last longer even though manufacturers okay their application in up to 100^{o}C. water.

Trouble Shooting

When discussing mechanical seal problems, the

following analogy may be made: Mechanical seals behave very much like bearings. Conditions that lead to bearing failure also lead to mechanical seal breakdown.

Misalignment

One of the main causes of mechanical seal failure is misalignment. This commonly occurs when seals are installed by personnel not trained in proper mechanical seal installation practices. If the seal is installed so that the mating faces are not parallel to each other and perpendicular to the shaft, the rotating face will try to square itself with the seat causing uneven wear on the mating faces.

To prevent this problem check to be sure that the seal is properly installed. The rotary unit must run parallel with the shaft and the stationary seat must be perpendicular to the shaft. Be sure the gland is drawn up evenly. This will eliminate the possibility of the improperly aligned stationary seat.

Lack of Lubrication

To operate properly, the mechanical seal mating faces must run on a liquid film. If there is no film, the seal will overheat and fail. Because this failure can occur in a matter of seconds, it is extremely important that the liquid film be present whenever the pump is in operation or about to be put into operation. Lack of lubrication at the seal faces is commonly experienced when handling light hydrocarbons near their vapor pressure. To ensure lubrication and dissipate heat, flushing must be provided at the seal faces.

Overheating

In some types of mechanical seal failures, overheating and lack of lubrication go hand in hand. This is

especially true when the hard face heat checks. On examining a hard face that has heat checked you can see that the stress cracks are confined to the surface in direct contact with the carbon mating face. These surface cracks are caused when there is an intense heat buildup on the surface of the hard metal, while the sub-surface metal is not allowed to expand in a lineal direction because of the sub-surface temperature, the surface buckles upward and cracks. The edges of the cracks, which are slightly raised above the face, begin to shave material from the carbon mating face.

Other symptoms of overheating are damaged elastomers. This condition is easily recognized because the elastomers will show cracking on the surface and harden.

To eliminate this type of failure, be sure the seal is operated in an environment having a lower temperature than the limits of any of its component parts.

Abrasive Damage

Abrasive damage is a common cause of seal failure. When minute abrasive particles work their way between the seal faces, they can groove the mirror finish of the faces or they can leave deposits from evaporation of the liquid. When these deposits build up on the shaft they will freeze the sealing elements to the shaft and eliminate all seal flexibility. This condition can be particularly acute when teflon sealing wedges are incorporated in the seal. Abrasive particles may become imbedded in the teflon, and can cause shaft wear directly under the sealing member. Abrasive liquids should be kept out of the stuffing box if at all possible.

Corrosion

Corrosion failure is easily recognized in most cases. Metal parts show signs of pitting, or the sections

are totally corroded away. We will not attempt to go into a discussion of corrosion, but it should be remembered that the metal sections of mechanical seals are usually much smaller than the metal section of a pump. Therefore, they can withstand much less corrosion attack. It is a good rule not to down-grade the metallurgy of the seal from that of the pump. When in doubt, select the more noble metal for the seals. (This is a general rule and does not hold true for all applications.)